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DEVELOPMENT AND TEST OF FIBERGLASS LOW-IMPACT RESISTANT TOWERS.(U)
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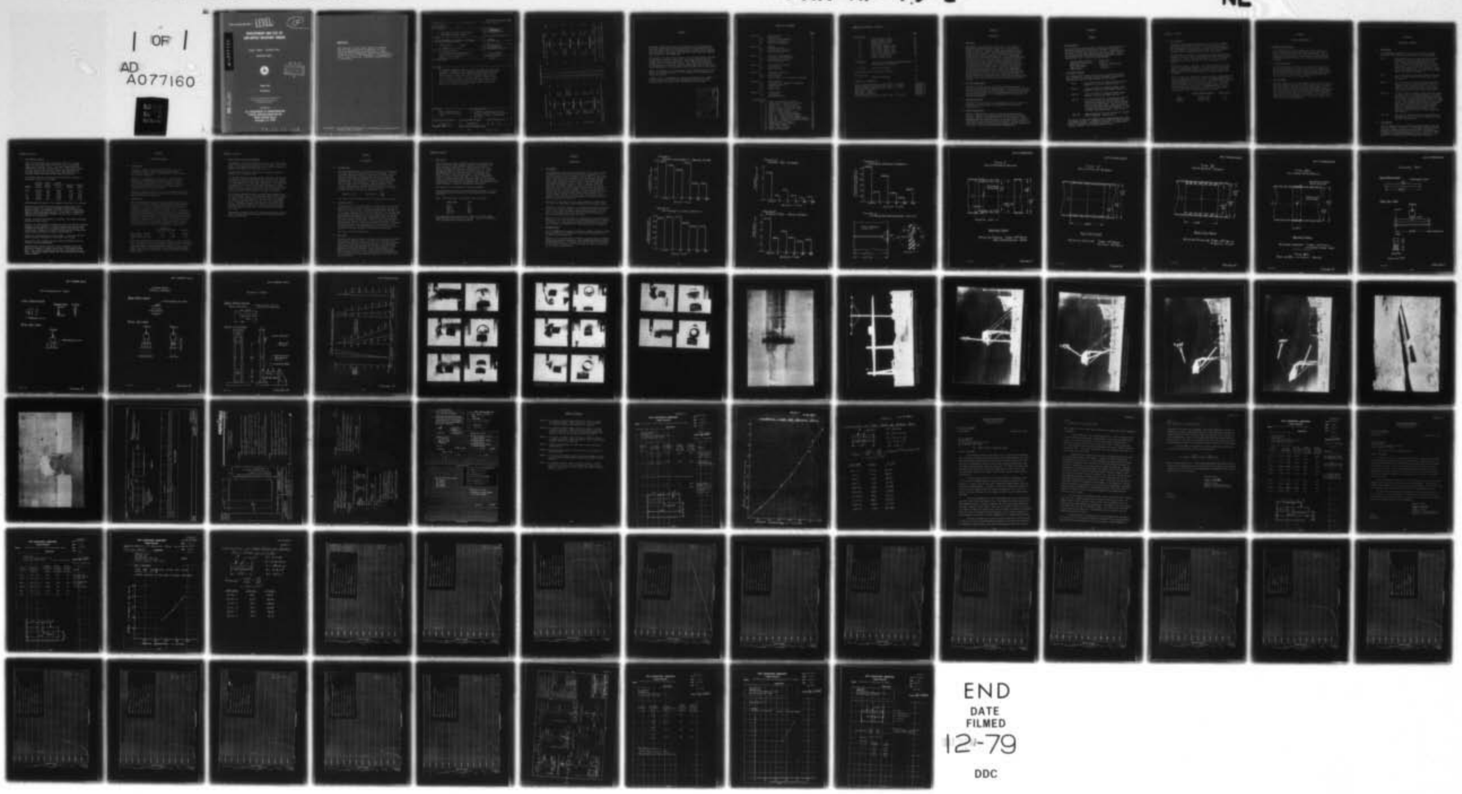

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DEVELOPMENT AND TEST OF LOW-IMPACT RESISTANT TOWERS

Eugene T. Rogers   Jonathan A. Ross

Kenneth M. Snyder

August 1979

Final Report

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U.S. DEPARTMENT OF TRANSPORTATION
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Airway Facilities Service
Washington, D.C. 20591

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16. Abstract

A break-away fiberglass mast for use in low impact resistant (LIR) structures to support airport approach lighting systems has been developed. This design will withstand 100 mph winds (including gusts) without ice and 75 mph winds (including gusts) with a 1/2 inch radial ice load. Yet, when struck by a light airplane wing, it breaks into pieces without catastrophic damage to the wing. It was observed that impact energy needed to break the mast was in the order of 679 foot-pounds and that peak forces were in the order of 5,656 lbs.

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Unclassified	Unclassified	76	

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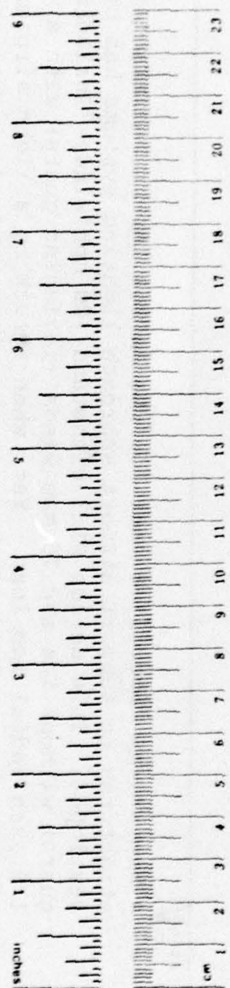
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

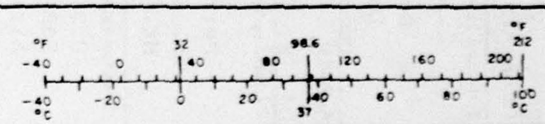
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Preface

The Visual Landing Aids Branch of the Federal Aviation Administration contracted with Permali, Incorporated to develop a break-away mast for use in low impact resistant (LIR) structures to support airport approach lighting systems. This report describes that effort which was conducted under Contract No. DOT-FA78WA-4152.

The proposal to do this work at Permali, Inc. was unsolicited by the FAA. It was based on Permali's expertise in the design and manufacture of filament wound glass with epoxy resin. This combination of materials has the traits of exceptional strength, light weight, and durability. In combination with additives that will protect the material from ultraviolet degradation, it is expected to have a minimum life of twenty years.

Permali is indebted to Dr. Jamil Abassi and Mr. Stephen Cannistra of the Federal Aviation Administration for the cooperation and guidance which they have provided.

We wish, also, to acknowledge the valuable contribution of Dr. Roger G. Slutter and his staff at the Fritz Engineering Laboratory of Lehigh University where the impact tests and analyses were performed.

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SECTION 1

Introduction

1.1 Background

The concern of the FAA for the safety of aircraft crews and passengers has been exhibited in many ways. The potential hazard of striking the support towers of the Approach Lighting System has lead to a number of design and development efforts during the past decade. In 1975 a development contract was placed with Lev Zetlin Associates, Inc. for the development of a design for an advanced LIR structure of non-metallic materials. The objectives were to achieve minimum interference with the localized beam of the Instrument Landing System and provide a light weight, low mass system. The resulting design utilized a filament wound glass/resin tube of high strength with stress raising notches to initiate failure on impact. This design was produced in limited quantity. Impact tests subsequently revealed energies and peak forces greater than those predicted by the engineering design analysis. Permali, Incorporated, the manufacturer of these units, proposed to the FAA a program for the development of a break-away joint to replace the stress raising notches. This report details the contract resulting from this proposal.

1.2 Contract Requirements

Provisions of this contract provide for three basic phases: (a) The characterization of the existing design, utilizing stress raising grooves, in both static and dynamic modes; (b) The design and testing of our different concepts for a break-away mechanism to replace the stress raising grooves; (c) The optimization of two concepts for a break-away mechanism.

1.3 Contract Objective

The object of this contract is to determine the most cost effective design for a LIR mast which will meet the desired break-away characteristics.

1.4 Report Organization

Section 2 summarizes the results of the testing which was done. Section 3 details the governing parameters within which the work was done. Section 4 describes the four joint concepts for a break-away mechanism and gives the details of the test results. Section 5 describes the two concepts which were optimized and gives the details of the test results. Section 6 gives details of the test methods used and Section 7 presents conclusions and recommendations.

SECTION 2

Summary

2.1 Existing Design

The LIR masts are presently made in accordance with specifications FAA-E-2640, FAA-E-2659 and applicable drawings. This design utilizes a V shaped notch (see Fig. 6, pg. 14) at spaced intervals as the means of attaining the desired break-away joint. Tests on this existing design established strength properties as follows (see Figures 11, 12, 13 and 14 for test methods):

Flexural Moment Capacity	-	126,450 in.lb.
Compressive Load Capacity	-	56,400 lb.
Shear Load Capcity	-	39,000 lb. (double shear)
Impact Peak Force	-	9,100 lb.
Impact Energy	-	2,500 ft.lb.

2.2 Provisional Concepts

Four concepts were devised with the view to provide for a clean impact break while retaining sufficient strength to withstand the required wind loading. These concepts were as follows:

- Type I - A male-female joint with the male portion being composed of hoop wound fibers (see Fig. 7).
- Type II - A joint utilizing an internally bonded sleeve composed of helically wound fibers (see Fig. 8).
- Type III - A joint utilizing an internally bonded sleeve composed of hoop wound fibers (see Fig. 9).
- Type IVa - A joint accomplished by introducing an integral, hoop wound, ring at the time of winding the tube and then machining off the helical windings over the ring after curing. Four 1/4" diameter holes were drilled through the centerline of the integral hoop wound ring, at 90^{o} spacing, in order to insure fiber discontinuity. (See Fig. 10).
- Type IVb - Same as Type IVa, but with the four 1/4" diameter holes eliminated. (See Fig. 10).

The results of static and dynamic tests of these concepts are shown on Figures 1 through 5. Comparison is made with the current design which is identified in the figures as "Notch". All values shown in Figures 1 through 5 are ultimate strength values.

2.3 Final Concepts

Two design concepts were developed which, by test, have adequate strength for the intended service and which will break clean when impacted by an aircraft wing. Of these two design concepts, one is intended for new manufacture and the other is intended for the modification of masts which are already in existence.

New Manufacture - Design A: This design utilizes helically wound, integral rings which, when the overwound main tube fibers have been machined off, provide fiber discontinuity so that the resulting impact break is clean (see Dwg. No. F-F-8161, Details A & B on page 35).

Modification Concept - Design B: This design consists of a break-away joint produced by cementing in an internal, helically wound sleeve of such dimensions that the various criteria are met but, because there are no continuous fibers, a resultant impact break is clean.

Since the shear and compression loading, resulting from maximum wind force, is adequately covered by all designs tested, these factors can be eliminated from decision making. The maximum moment resulting from maximum wind force is 36,640 in.lb. (see Fig. 15) and this occurs at the base line. The first frangible joint is 38-1/2" above the base line; therefore, the maximum moment to be seen by any joint would be 28,438 in.lb. A comparison of the existing design (Notch) and the final concepts is as follows:-

	Flexural Moment Capacity	Safety Factor
Notch	126,450 in.lb.	4.5
Design A	128,430 in.lb.	4.5
Design B	103,680 in.lb.	3.7

SECTION 3

Contract Requirements

3.1 Existing V-Notch Design

It is required that the existing V-notch design (see Fig. 6, page 14) be characterized in both static and dynamic modes in order to provide a benchmark for comparison purposes. It is recognized that the existing V-notch design lacks the desired break-away characteristics in that it will not separate cleanly on impact.

3.2 Preliminary Concepts

It is required that a minimum of four separate break-away joint concepts be developed as a means of arriving at a design which would resist the specified wind loading of 100 mph (with gusts) and yet be sufficiently frangible to break cleanly when impacted by the wing of a light aircraft. These concepts are to be characterized by static and dynamic tests.

3.3 Final Concepts

Two final concepts are to be developed, making full use of the test experience with the preliminary concepts, and these two concepts are to be tested in both the static and dynamic mode. It is required that these two concepts separate cleanly when impacted, that they have sufficient moment resistance to withstand the required wind loading and that they be cost effective. It is further required that the final concepts be reliable in performance and that they have the required service life of 20 years in outdoor use ($\pm$ 55°C and 5% to 100% humidity).

SECTION 4

Preliminary Concepts

4.1 Construction

Five preliminary concepts of break-away joints were developed and tested, one of which was a variation of one of the others.

Type I - A male-female joint with the male portion being composed of hoop wound fibers and having four 1/4" diameter holes, spaced 90° apart, at the line of juncture of the two sections of helically wound tubing. The male portion of the joint is wound as an integral part of one section of tubing and is then cemented into the female end of another section of tubing. See Figure 7.

Type II - A joint utilizing an internally bonded sleeve composed of fibers wound with a helix angle of 45°. See Figure 8.

Type III - A joint utilizing an internally bonded sleeve composed of hoop wound fibers and having four 1/4" diameter holes, spaced 90° apart, at the line of juncture of the two sections of helically wound tubing being joined by the sleeve. See Figure 9.

Type IVa - A joint in which an integral, hoop wound ring having a double taper on the outside diameter is placed on the mandrel at the time when the main tube is wound. This integral ring is overwound by the helical fibers of the tube and becomes an integral part of it during curing. The overwound helical fibers are machined away from the central portion of the ring, thus breaking the continuity of the helical fibers. Four 1/4" diameter holes are drilled, on 90° spacing, at the center point of the integral ring. See Figure 10.

Type IVb - This joint is constructed exactly as Type IVa with the exception that the four 1/4" diameter holes are omitted. See Figure 10.

4.2 Test Results

The test results on the preliminary concepts are shown on the bar charts in Figures 1 through 5. The data supplied by the FAA indicates that, under the most severe wind loading, mast MG-20 is exposed to the greatest shear force (225 lb.) and that mast MG-40 is exposed to the greatest compressive force (3,250 lb.). (See Exhibit F of FAA Dwg. D-6155-1 for masts MG-20 and MG-40.)

4.2 Test Results (cont'd)

Since the lowest shear test values were 7,900 lbs. in single shear (1/2 the double shear shown on the chart), the minimum safety factor in shear is 35/1. The lowest compressive test values were 42,300 lbs. which results in a minimum safety factor of 13/1. As the safety factors in shear and compression are more than adequate for all construction types tested, we can eliminate these stress modes from further consideration.

The relevant factors for evaluating the preliminary concepts of break-away joints are as follows:-

Design	Flexural Strength In.Lb.	Impact Energy Ft.Lb.	Impact Peak Force Lb.	Relative Weight	Relative Cost
Notch	126,450	2,500	9,100	1.00	1.00
I	35,100	450	3,800	1.21	1.03
II	94,600	970	5,700	1.10	0.95
III	31,800	480	4,000	1.28	1.06
IVa	15,600	270	3,000	1.00	0.79
IVb	46,400	400	3,600	1.00	0.79

Relative weight is based on five frangible joints per 20 ft. section.

The existing or notch design is obviously the strongest of the group in flexure, but it requires excessive impact energy for a break and, when it is impacted, the notch or stress raising groove does not achieve complete separation. After impact, a substantial number of the fibers remain unbroken and, thus, the two parts of the mast do not separate.

Design I can not be considered as a solution. The flexural strength provides no safety factor.

Design II is a satisfactory construction in that the flexural strength provides a safety factor of 3.3 and it breaks completely on impact although the required force is somewhat greater than desired. The relative cost of Design II is about 5% lower than that of masts with stress raising grooves which makes it cost effective.

Design III is unsatisfactory in every sense. It has less than the required flexural strength and the relative cost is high.

Design IVa is cost effective but the flexural strength is too low to permit serious consideration.

Design IVb has a safety factor of 1.63/1 in flexure and is cost effective. However, on impact failure was in the material rather than in the integral ring/tube bond and all of the fibers did not break. This design showed promise, but also indicated that further work was needed.

SECTION 5

Optimized Concepts

5.1 Construction

Following a review of test data with FAA personnel, the decision was made to proceed with two design concepts which showed promise, but to introduce certain modifications for improved performance.

Design A is an adaptation of Design IVb. The hoop wound integral ring is replaced by a helically wound ring which is inherently strong enough so that, on impact, it will force a bond failure and, thus, a clean break. Production cost will be substantially the same as for Design IVb so that Design A will be cost effective.

Design B is similar to Design II, but the length of the wound sleeve was reduced to three inches in order to reduce the impact energy necessary for separation.

5.2 Test Results

Shear and compression tests were omitted because the experience in all prior testing showed that these properties were more than adequate in all cases. Flexural tests were performed at Mount Pleasant, PA, and impact tests were performed at the Fritz Engineering Laboratory of Lehigh University. The first samples of Design A were made with 1-1/2" long helix rings. Tests of these tube sections were distorted because not all of the continuously overwound fibers had been cut. They also lacked flexural strength because of inadequate bonding area at the break-away joint. After consultation with the FAA, it was decided to increase the length of the helix ring to three inches in order to improve flexural performance and to assure complete separation of the overwound fibers by machining. Results of the tests are shown below.

	Design A		
	1-1/2" Ring	3" Ring	Design B
Flex. Moment - In.Lb.	31,320	128,430	103,680
Impact Energy - Ft.Lb.	612	679	927
Impact Peak Force - Lb.	4,525	5,656	5,570

These tests indicate safety factors in flexure of 1.10 for Design A with 1-1/2" helix rings, 4.52 for Design A with 3" helix rings, and 3.65 for Design B. With the exception of Design A with 1-1/2" helix rings, both designs separated cleanly on impact with the failures taking the form of glueline shear. Design B achieves comparable moment, impact energy, and peak forces with reduced bond length as Design Type II.

5.3 Impact Test on Full Scale Prototype

The concept of Design A was chosen for a full scale impact test. A MG-20 mast, per Permali drawing F-F-8161 on page 35, was produced. It was made with helix rings, per F-A-8162 on page 36, to manufacturing specification MS-1259 on page 37.

The test was performed at the Naval Air Engineering Center at Lakehurst, NJ, in January 1979.

The mast was erected in the same manner as would be the case for an approach lighting system and the top cross bar, with lights, was fitted to the top of the mast. The left wing of a light aircraft was mounted on a steel frame attached to a "dead load car" (see photo P.28) so that it would impact the mast at a point approximately 15 ft. above the ground. The "dead load car" was pushed to attain a desired velocity and then released prior to reaching the mast which it struck at a speed of 69 knots.

When the wing impacted the mast, the mast broke cleanly at two of the break-away joints, the first break being at about the point of impact and the second being at the break-away joint nearest the ground. The upper portion of the mast fell to the ground near the mast base while the lower portion flew forward about 150 ft. The impact created a slot about 10 inches wide which extended from the leading edge of the wing back to the center spar (see photos P.33 and P.34), but there was minimal damage to the wing.

Photographs on pages 29 through 32 show the progression from the point of impact through the time when the wing had passed both sections of the mast.

SECTION 6

Test Methods

6.1 Flexural Test

This test was performed on a Tinius Olsen Universal Test Machine with load applied to the center point of the specimen. In order to prevent localized crushing of the tubes, the usual loading nose was replaced by a load applicator 2-1/2" long which was shaped to fit the outside diameter of the tubes and which had radiused edges. For all tests, the span was 72" and the cross-head speed was .500 inches/minute. Flexural moment capacity was calculated using the standard simple beam formula. The flexural modulus was calculated from the deflection formula for a simple beam using the load, W, and the deflection, y, over the straight portion of the load vs. deflection curve.

$$\text{Moment, } M = \frac{Pl}{4} \quad ; \quad \text{Deflection, } y = \frac{WL^3}{48IE}$$

See Figure 11 for the fixture used, and calculations on page 38.

6.2 Compression Test

The compression test was performed on a Tinius Olsen Universal Test Machine with the load being applied to the end of the specimen by means of flat steel plates. Specimens were carefully machined so that the end cuts were flat and parallel and at 90° to the tube axis. In all cases, the break-away joint was centered in the test specimen. The specimens used were 6" long for the Notch design, and Design Types IVa and IVb. Specimens for Design Types II and III were 8" long while those for Design Type I were 12" long. Varying lengths were required because, in order to obtain valid results, it was necessary that only the tube surface contact the pressure applicators and the break-away joints were not all of the same length. The crosshead speed was .050 inches/minute for all tests. Since total compressive load was reported, no calculation was necessary.

See Figure 12 for the fixture used.

6.3 Shear Test

The shear test was performed on a Tinius Olsen Universal Test Machine using special saddles to support the ends of the specimens and a shaped load applicator to distribute the load. In order to prevent crushing, and thus distortion of the results, three steel tubes were placed inside the specimens so that they coincided with the saddles and load applicator but left the center points of the break-away joints free to shear. Double shear was measured in order to obtain distortion free results and the readings reported are all double shear unless otherwise indicated. See Figure 13 for the fixture used.

6.4 Impact Test

This test was performed at the Fritz Engineering Laboratory of Lehigh University using equipment generally in accordance with the provisions of ASTM E208-75. A weight, usually 200 lb., having a rounded tip was dropped from a height of 7 ft. above the specimen which was held in a horizontal position. The specimen was held as a cantilever with the break-away joint being centered 6" away from the support. The specimen was so placed that the tip struck the tube at a point 12" beyond the center of the break-away joint. The total energy of the falling weight was known and the residual energy, after tube failure, was calibrated by the distortion of aluminum plugs. By subtraction, the energy necessary to break the specimen was determined.

See Figure 14 for illustration of the test equipment.

Photographs were taken of the resulting impact failures. The clean separations in Type II and Type IV can be clearly seen (see pages 24 and 25).

Note: Coded references in the photos relate as follows:

Design Type	Code
Notch	KN
Type I	MF
Type II	SLHL
Type III	SHP
Type IV	INR

High speed motion pictures were also taken of the Lehigh tests. These are quite dark and difficult to see. They will be submitted to the Contract Officer with this report.

SECTION 7

Conclusions

7.1 Performance

The existing mast design which incorporates stress raising grooves is mechanically strong but lacks the desired frangibility. It does not break clean and the impact force necessary is much higher than is desirable. Data supplied by the FAA indicates that mast MG-20, under maximum wind conditions, develops greater maximum moment and shear stress than other masts. Mast MG-40 develops the greatest compressive stress. Since all designs tested had compressive and shear strength of such an order that the safety factor was quite high, these properties do not meet the same consideration given to flexural moment. Figure 15 illustrates the stresses over the length of mast MG-20. From this data it will be readily seen that the mast with stress raising grooves, with a flexural moment capacity of 126,450 in.lb., has a safety factor in flexure of 4.45 and could thus be weakened in flexure in order to supply the required frangibility.

Design Type II was the only one of the preliminary concepts which fully met the requirements although Design Type IVb showed promise.

Design A, of the final concepts, is a modification of Design Type IVb but differs in that the wound-in ring has helical rather than hoop fibers. This change increases flexural moment capacity to a safe level and guarantees that impact failure will be by bond failure which insures that the break will be clean.

Design B, of the final concepts, is a modification of the preliminary Design Type II in that the internal helically wound sleeve is reduced in length to 3". This design, on impact, breaks clean in glue line shear although the required force is slightly greater than desired.

7.2 Recommendations

It is recommended that Design A, as shown on Permali Drawings F-F-8161, FA-8162 and MS-1259, be considered the preferred design and that it be used for new construction.

Design B is an effective means of modifying existing masts of constant diameter for greater frangibility. The problems presented by tapered and preassembled masts as in specifications FAA-E-2640 and FAA-E-2659 and applicable drawings are different enough to require more testing to prove their practicability.

FIGURE 1

SHEAR LOAD CAPACITY (DOUBLE SHEAR)

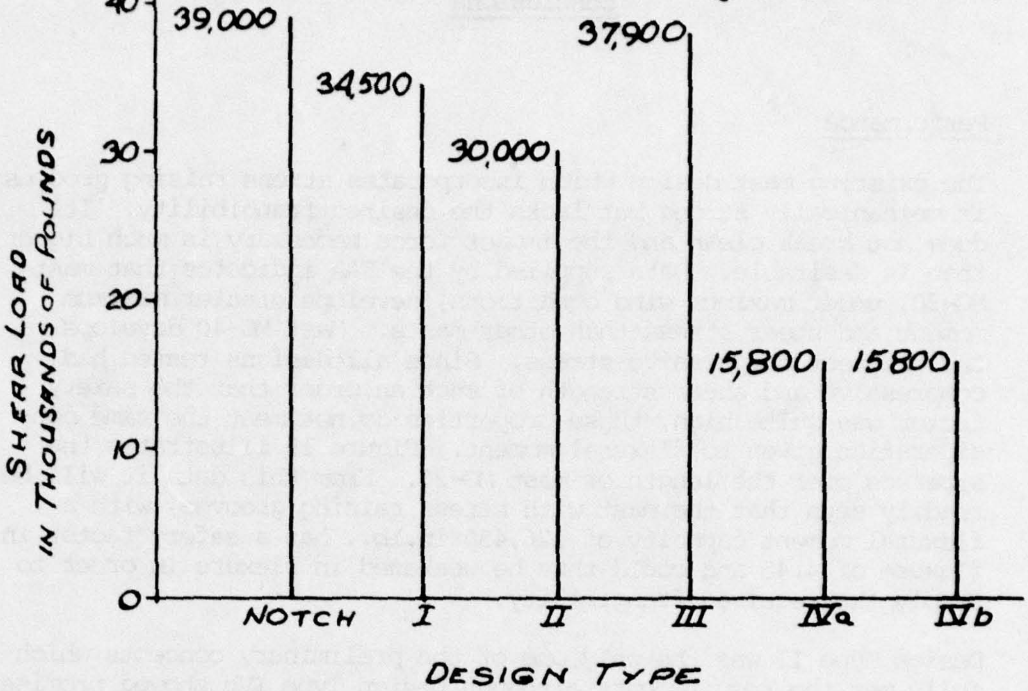


FIGURE 2

COMPRESSIVE LOAD CAPACITY

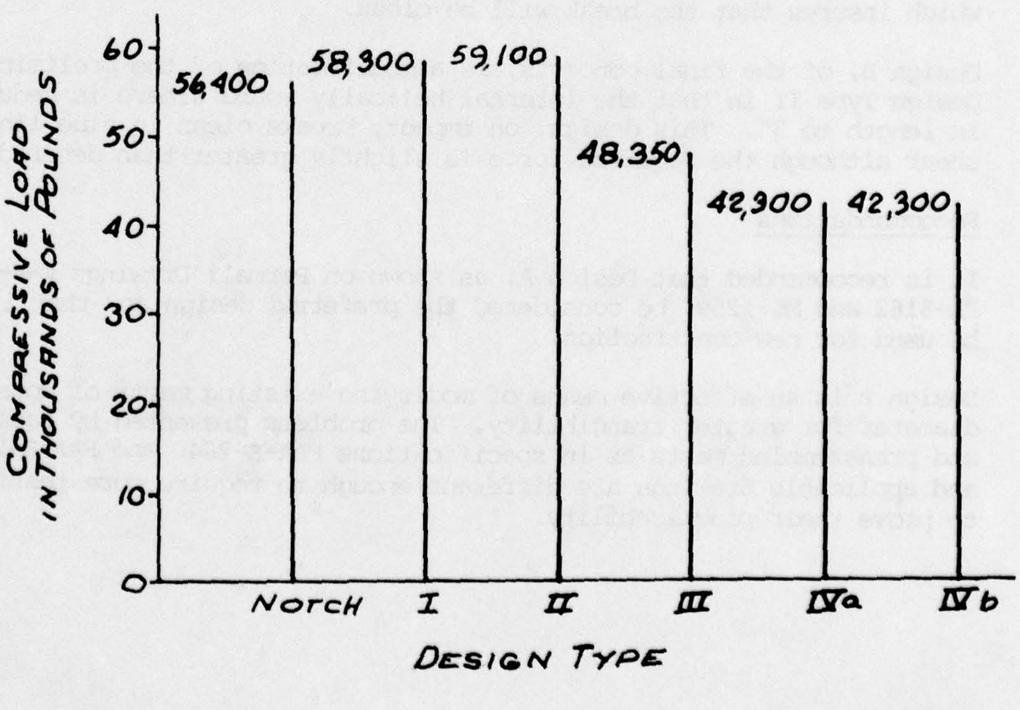


FIGURE 3
IMPACT TEST - ENERGY

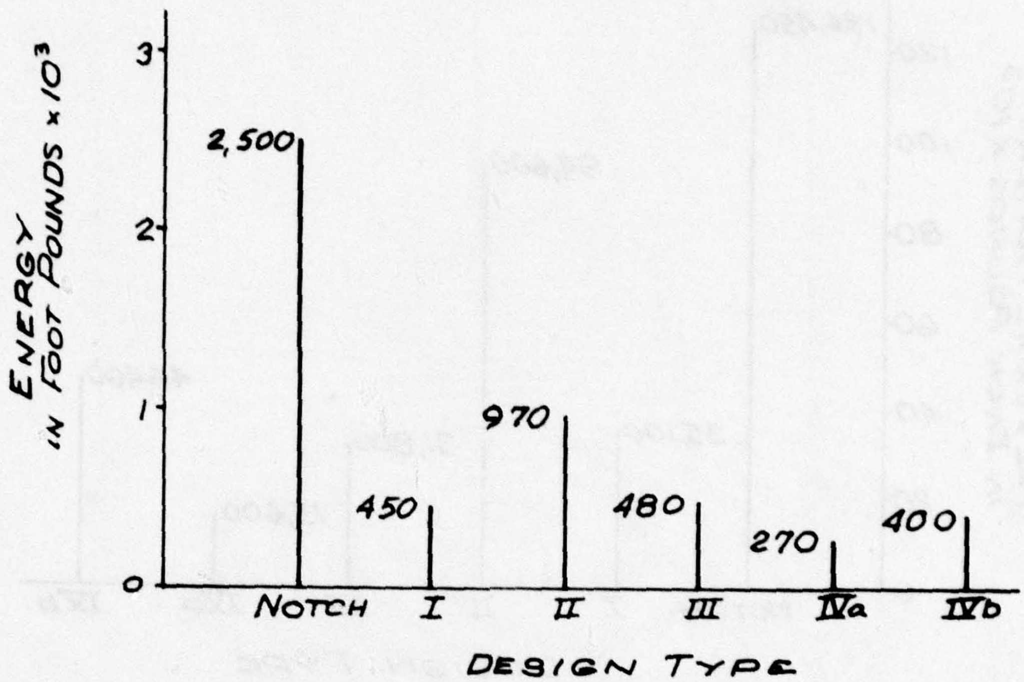


FIGURE 4
IMPACT TEST - PEAK FORCE

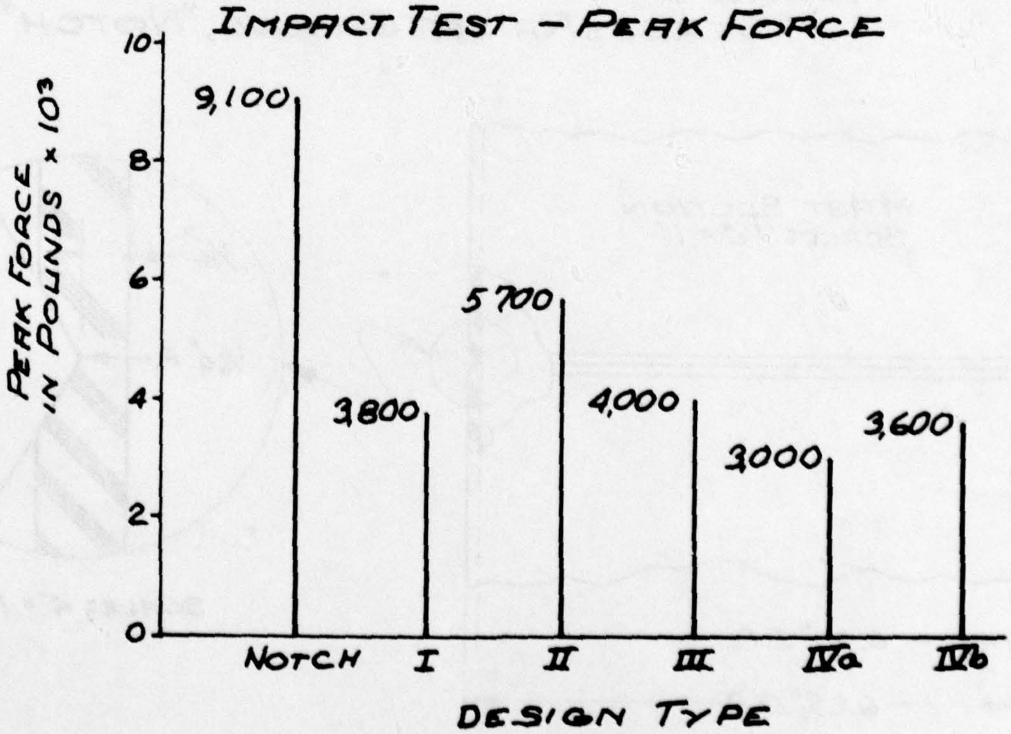


FIGURE 5
FLEXURAL MOMENT CAPACITY

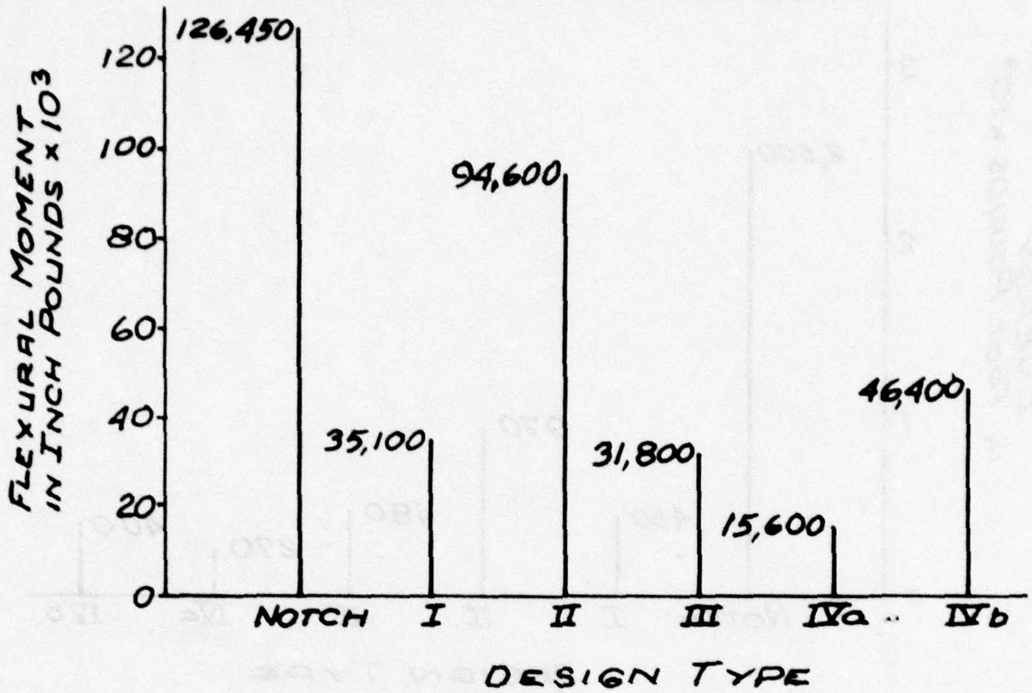
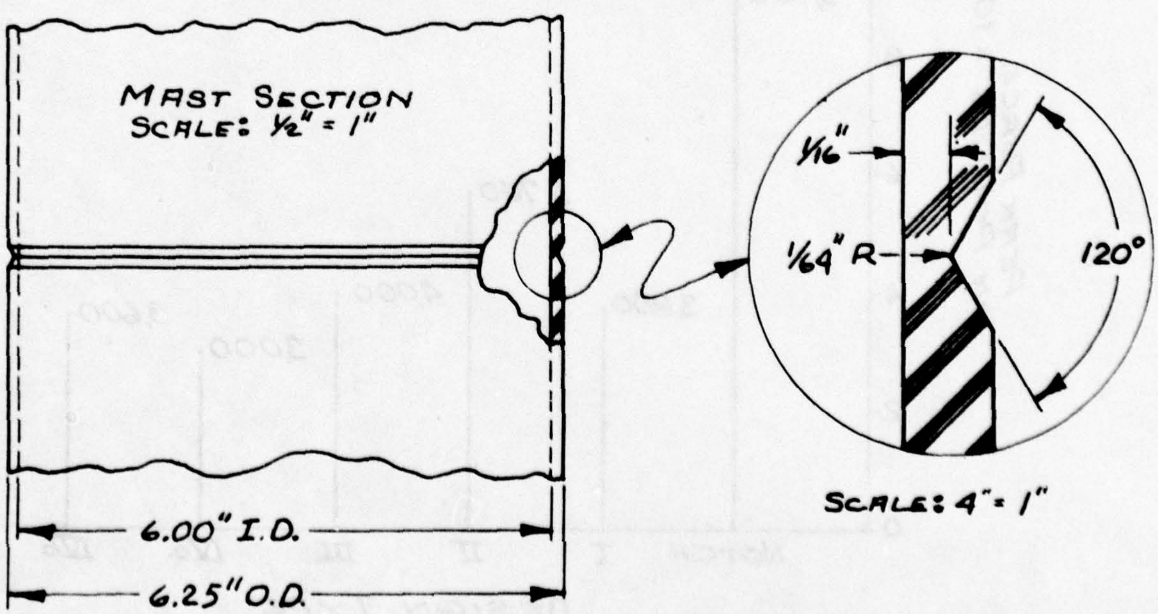
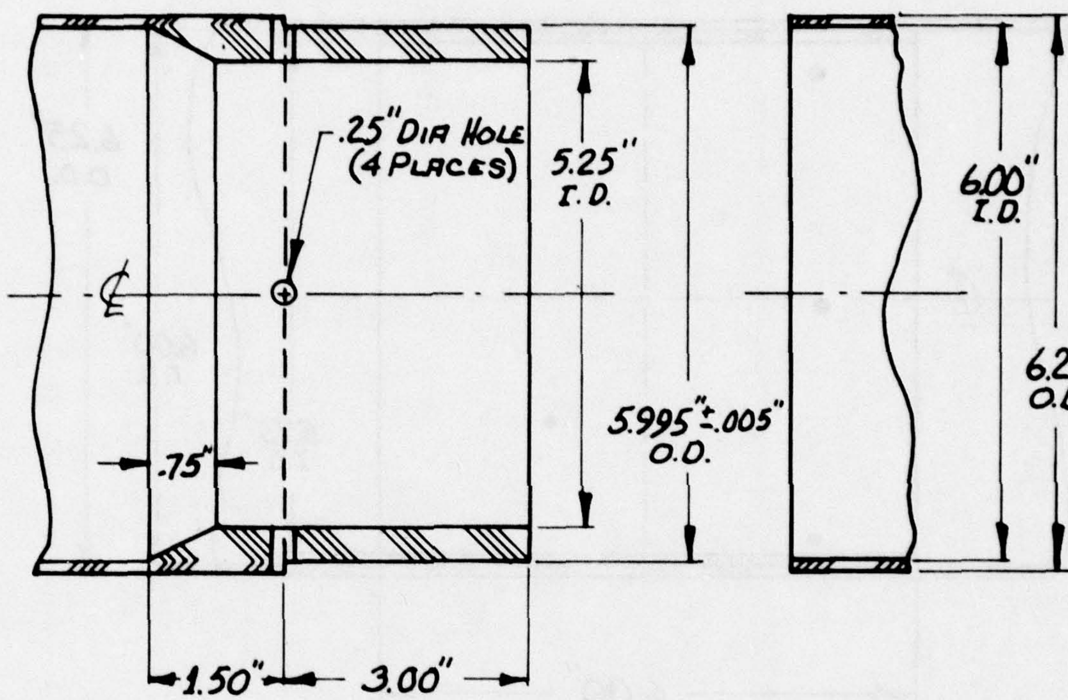


FIGURE 6
STRESS RAISER GROOVE, "NOTCH"



TYPE I
MALE/FEMALE DESIGN



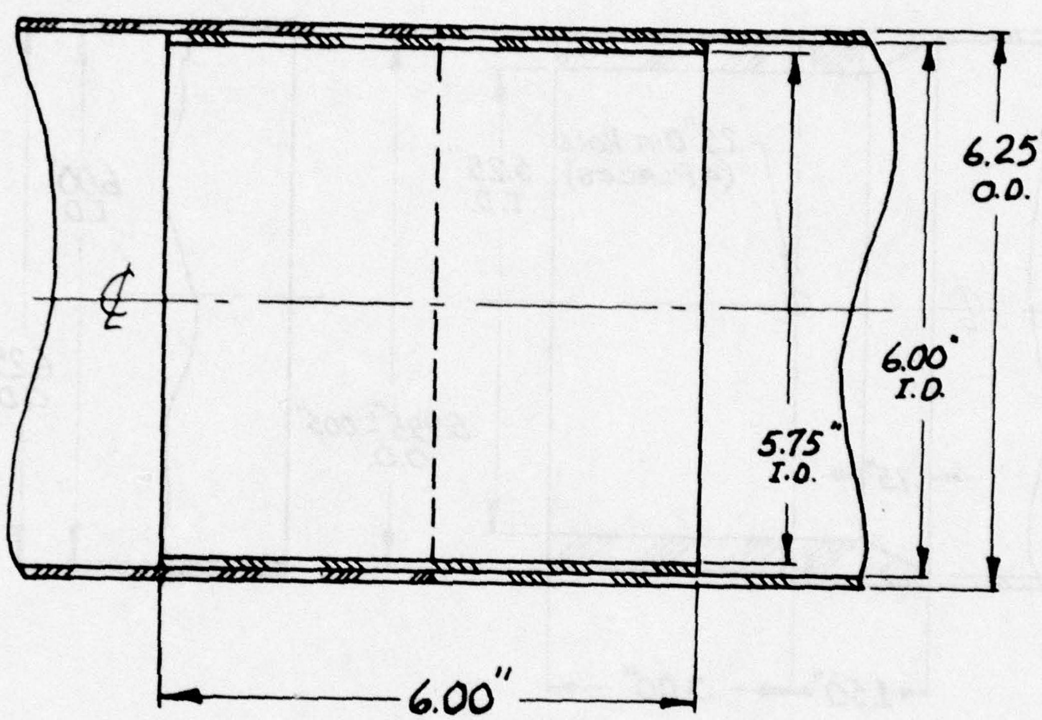
SECTION VIEW

WINDING ANGLE: TUBE - 20° HELIX
MALE PROTRUSION - HOOP

R 6·5·79

FIGURE 7

TYPE II
HELIX SLEEVE DESIGN



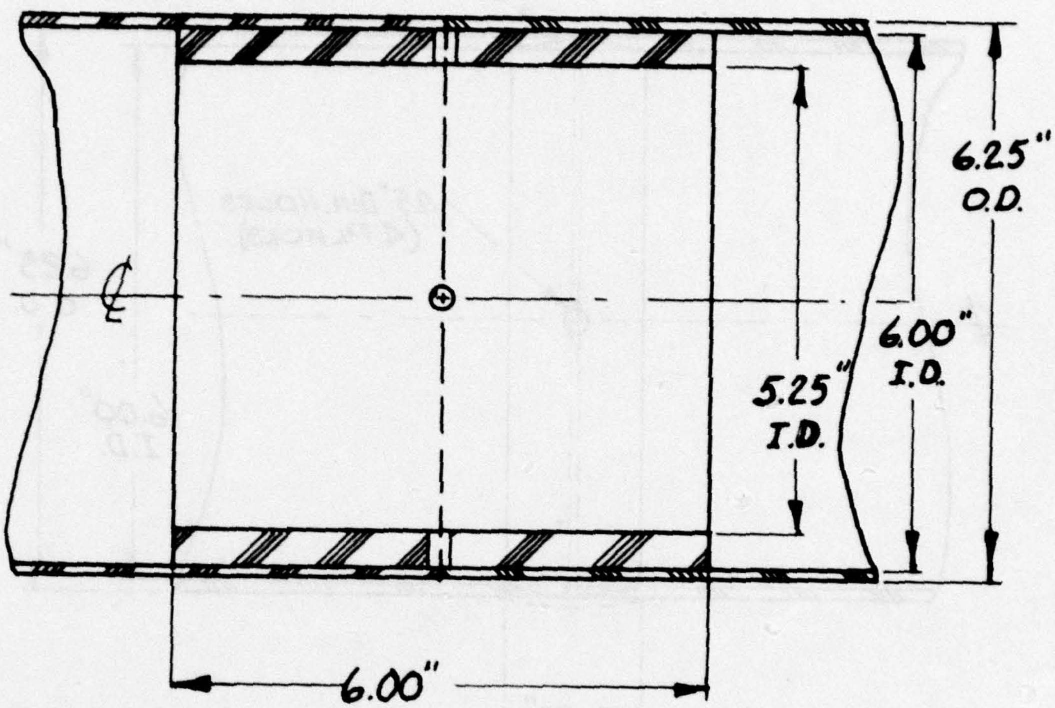
SECTION VIEW

WINDING ANGLES: TUBE - 20° HELIX
SLEEVE - 45° HELIX

R 6-5-79

FIGURE 8

TYPE III
HOOP SLEEVE DESIGN



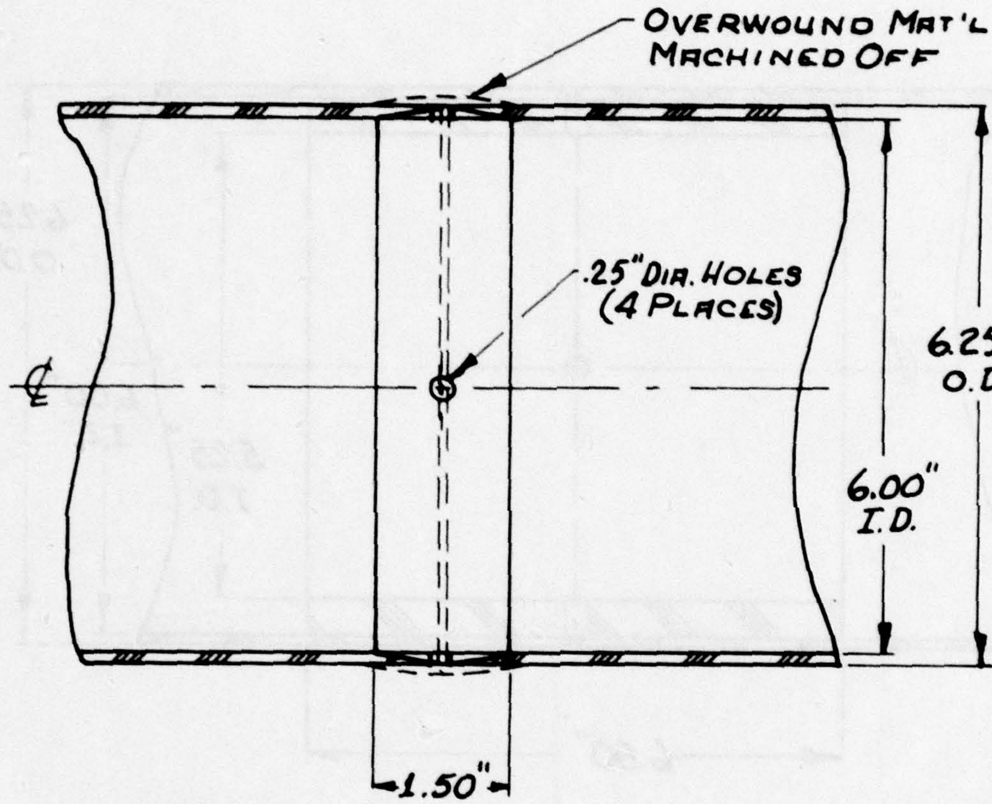
SECTION VIEW

WINDING ANGLES: TUBE - 20° HELIX
SLEEVE - HOOP

R 6-5-79

FIGURE 9

TYPE IVa
INTEGRAL RING DESIGN



SECTION VIEW

WINDING ANGLES: TUBE - 20° HELIX
INTEGRAL RING - HOOP

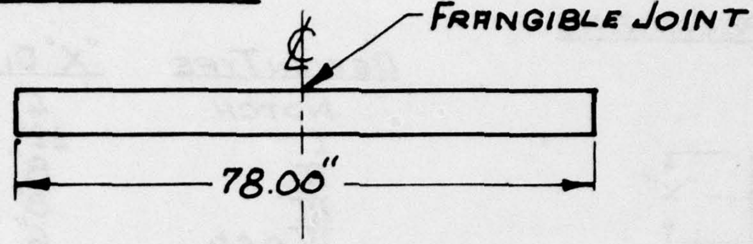
TYPE IVb
SAME AS IVa WITHOUT HOLES

R 6-5-79

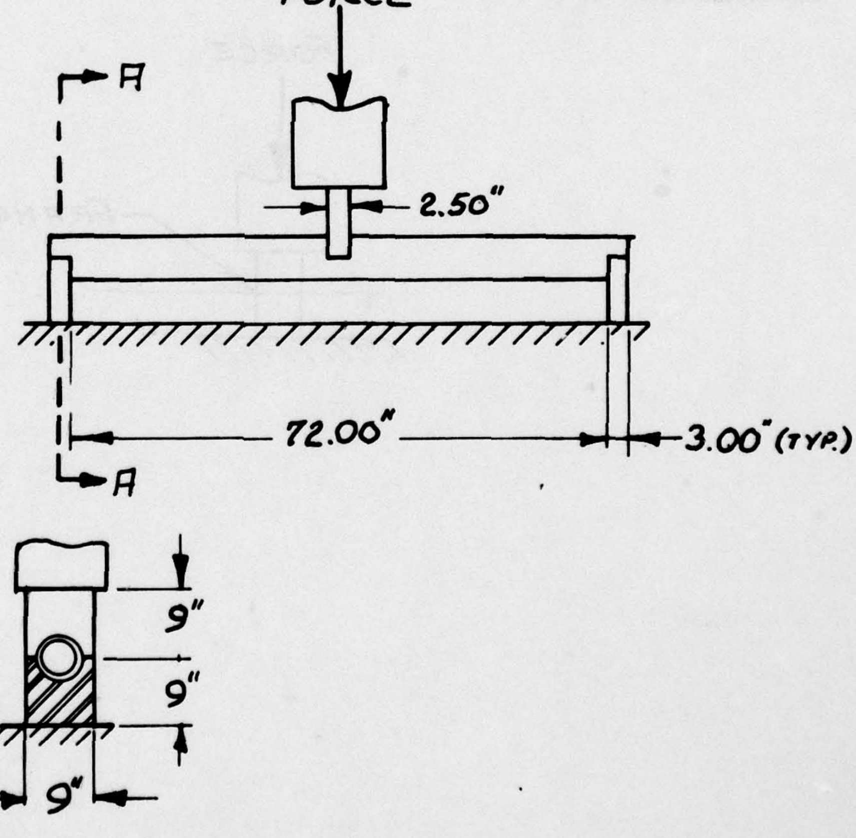
FIGURE 10

FLEXURAL TEST

TEST SPECIMEN:



TEST SET-UP:



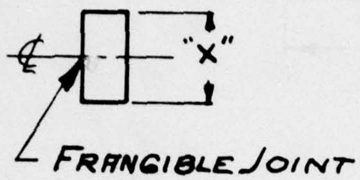
SECTION "A-A"

R 6-5-79

FIGURE 11

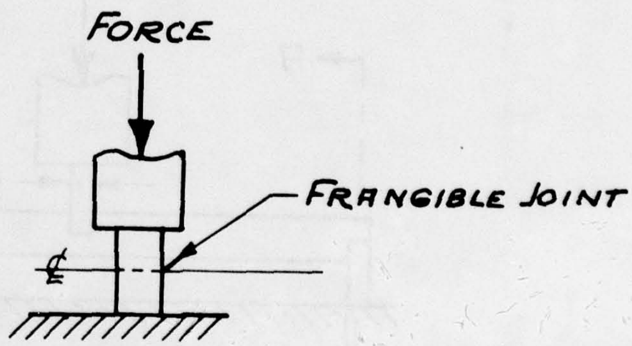
COMPRESSION TEST

TEST SPECIMEN:



DESIGN TYPE	"X" DIM.
NOTCH	6"
I	12"
II	8"
III	8"
IV a & b	6"

TEST SET-UP:

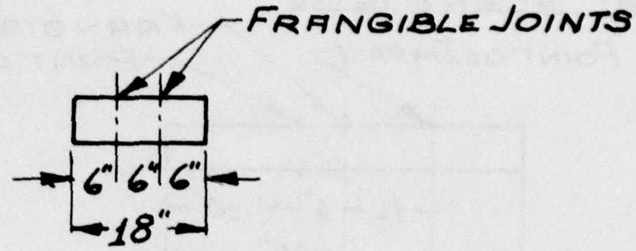


R 6-6-79

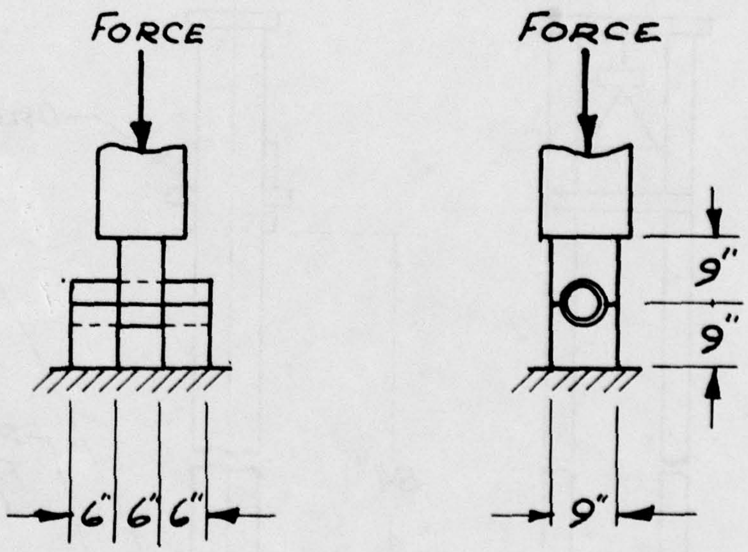
FIGURE 12

SHEAR TEST
(DOUBLE SHEAR)

TEST SPECIMEN:



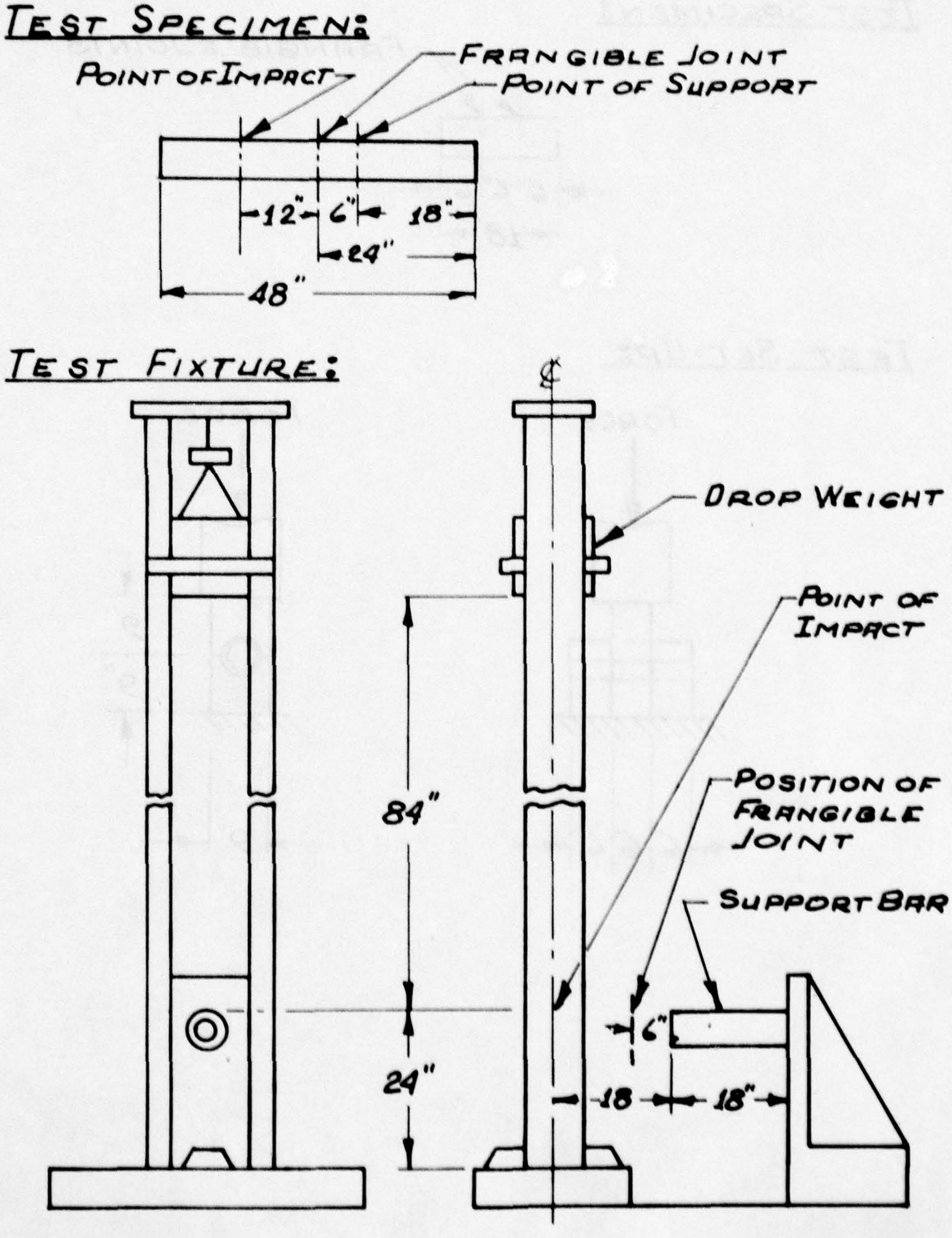
TEST SET-UP:



R 6-6-79

FIGURE 13

IMPACT TEST



R 6-6-79

FIGURE 14

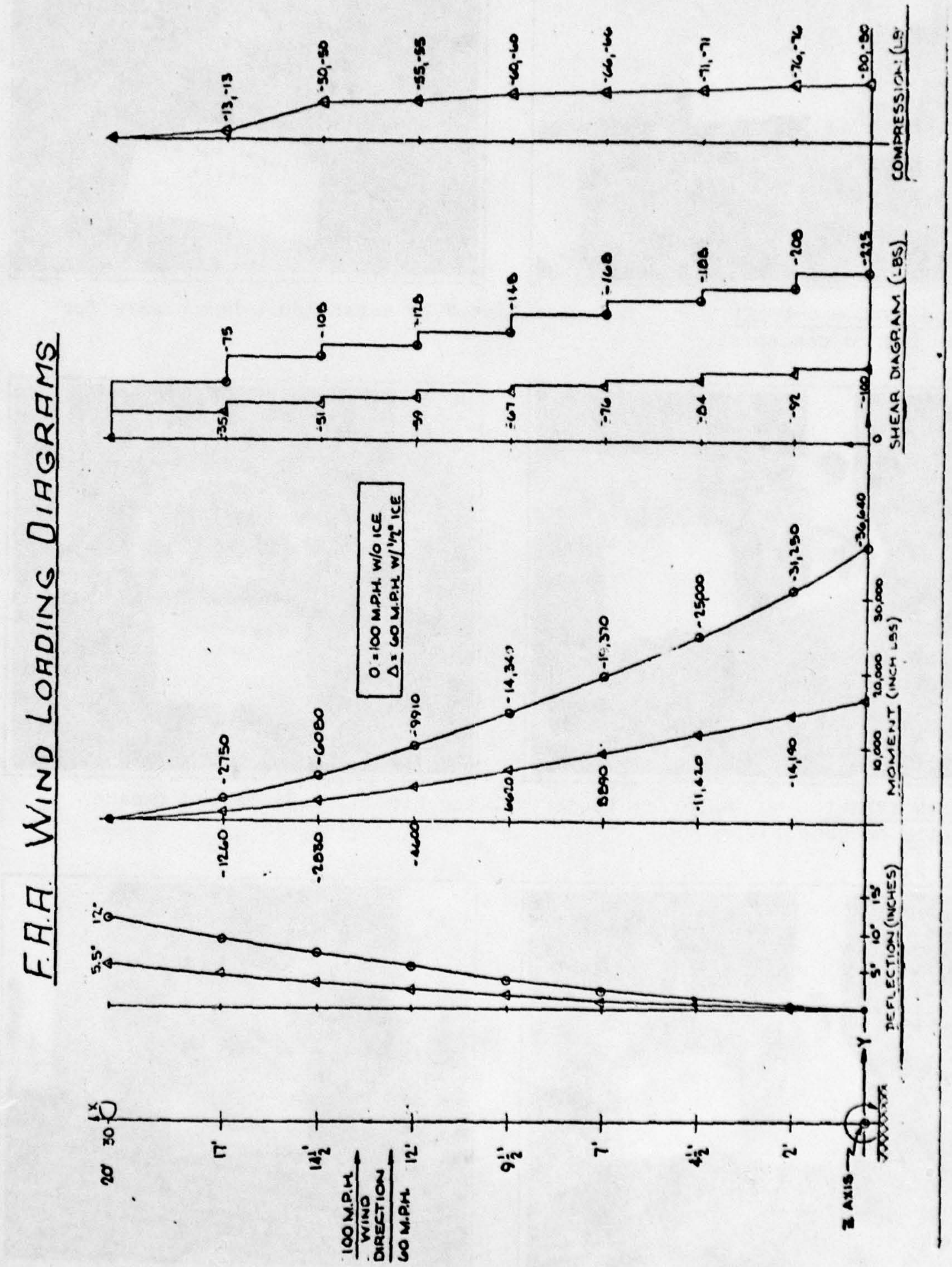
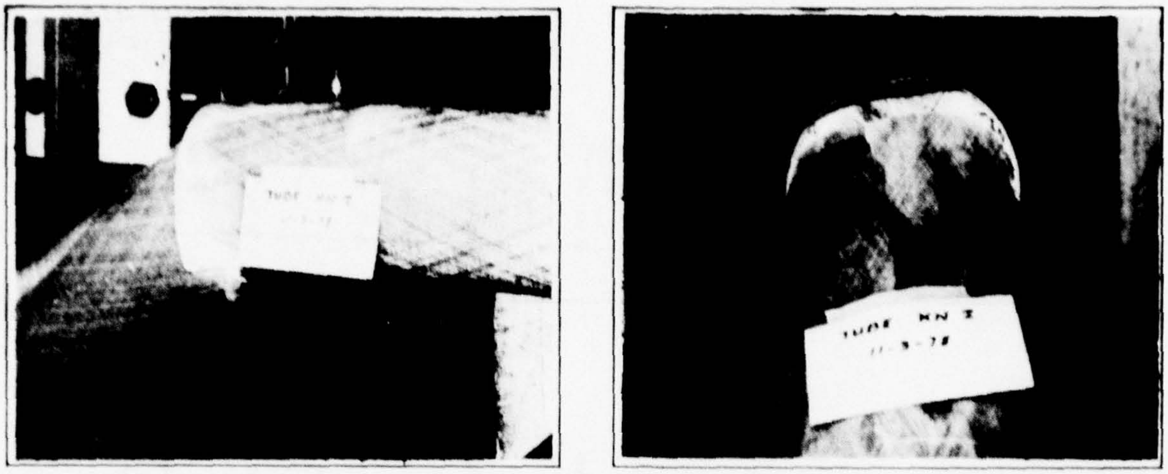
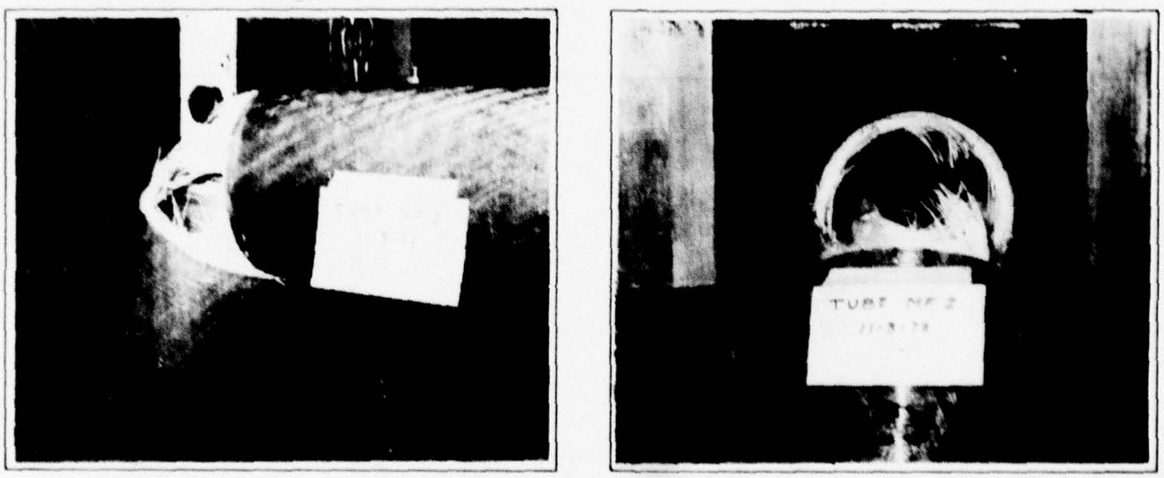

F.A.A. WIND LOADING DIAGRAMS
O = 100 M.P.H. W/O ICE
Δ = 60 M.P.H. W/1½" ICE
100 M.P.H.
WIND DIRECTION
60 M.P.H.
20' 30"
17'
14½'
12'
9½'
7'
4½'
2'
Z AXIS
Y
X
5.5"
12"
5" 10" 15"
DEFLECTION (INCHES)
-1260
-2030
-4400
-6620
-8890
-11,620
-14,190
-2750
-6080
-9910
-14,360
-19,370
-25000
-31,250
-36,640
10,000 20,000 30,000
MOMENT (INCH LBS)
-35
-51
-59
-67
-76
-84
-92
-100
0
-75
-105
-125
-145
-168
-188
-208
-225
SHEAR DIAGRAM (LBS)
-13,-13
-50,-50
-55,-55
-60,-60
-66,-66
-71,-71
-76,-76
-80,-80
COMPRESSION (LB)

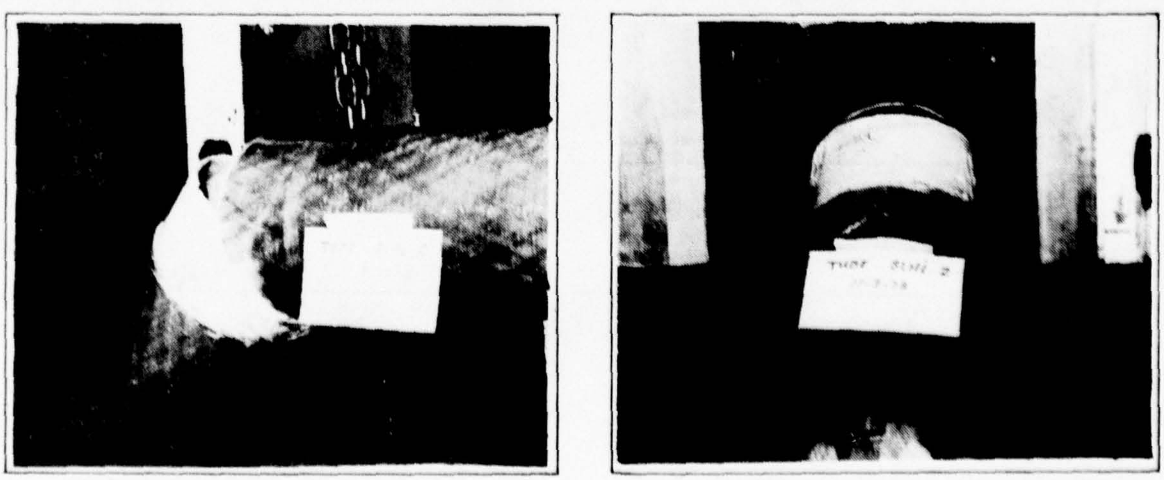
FIGURE 15



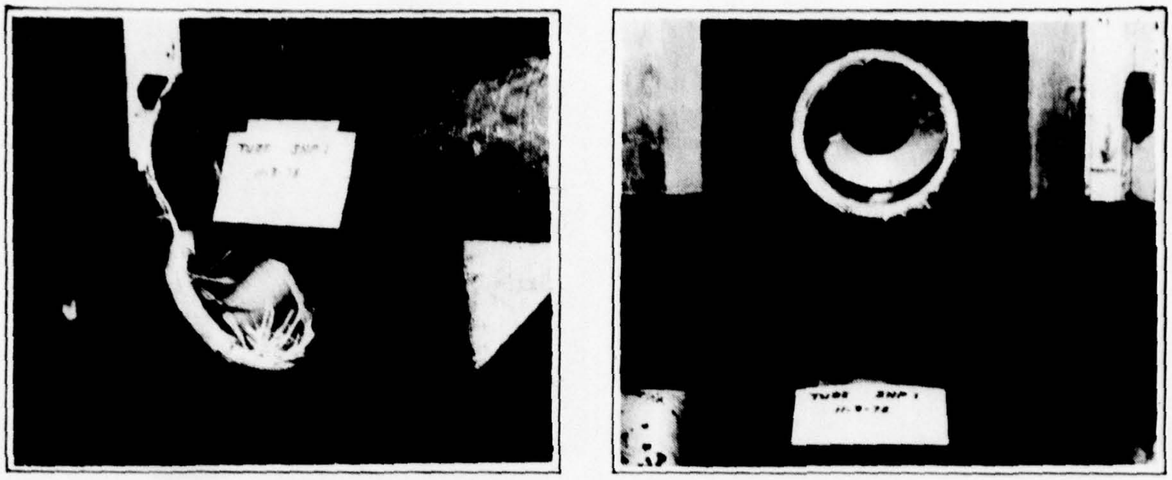
DESIGN TYPE - V-NOTCH - This was tested to establish a bench mark for later design concepts.



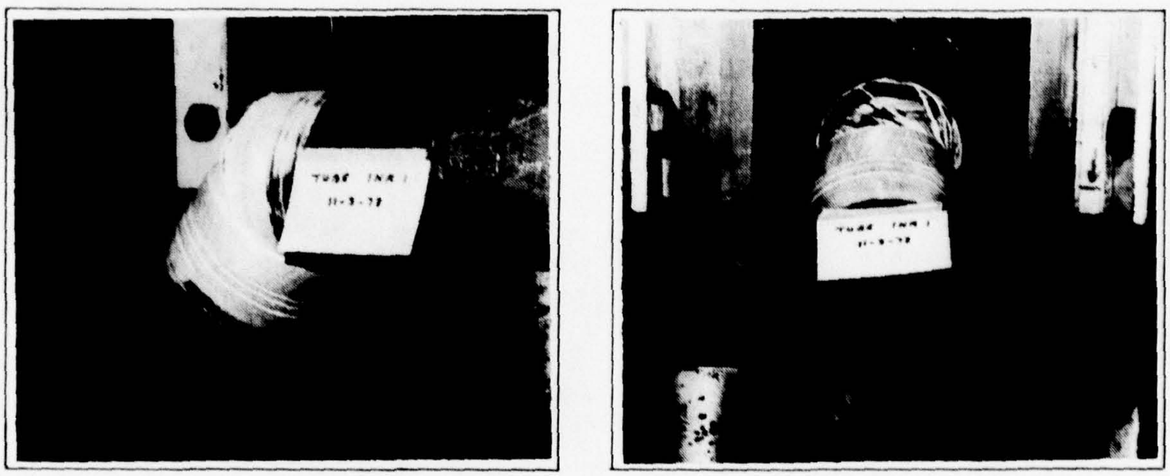
DESIGN TYPE I - Male female design, see Fig. 7, page 15 and impact results on page 13.



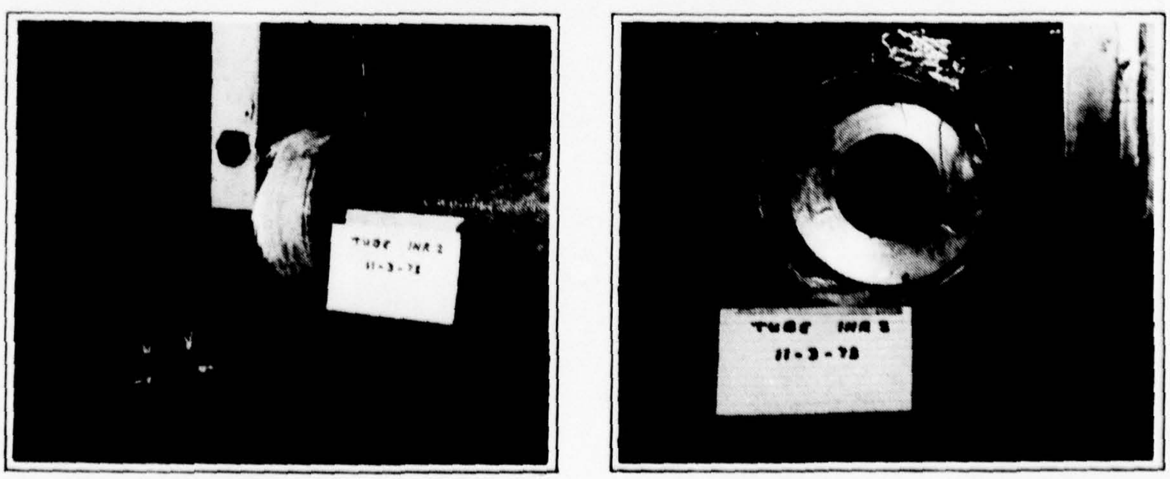
DESIGN TYPE II - Helix sleeve design, see Fig. 8, page 16 and impact results on page 13.



DESIGN TYPE III - Hoop sleeve design. See Fig. 9, page 25 and impact results on page 13.

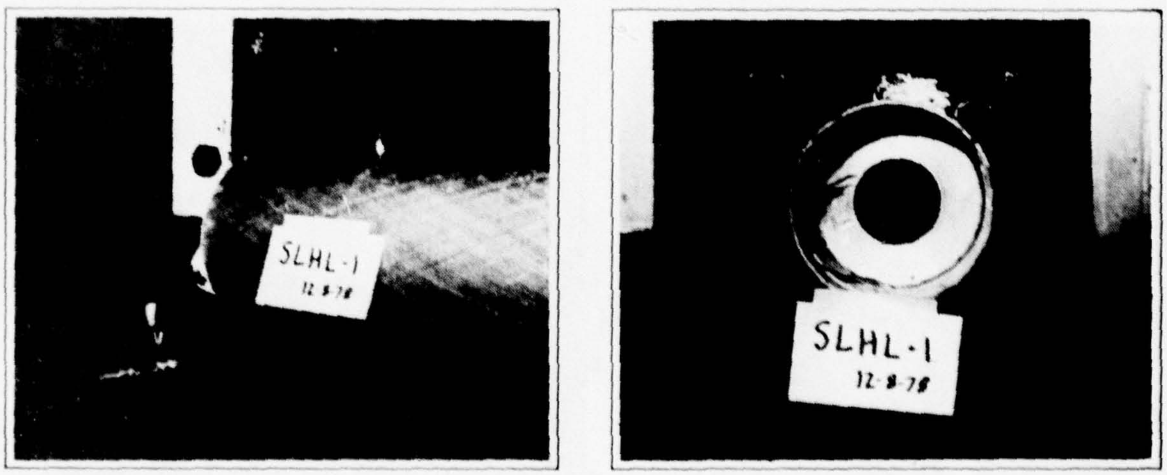


DESIGN TYPE IVa - Integral ring design with four (4) holes drilled 90°. See Fig. 10 and impact results on page 13.

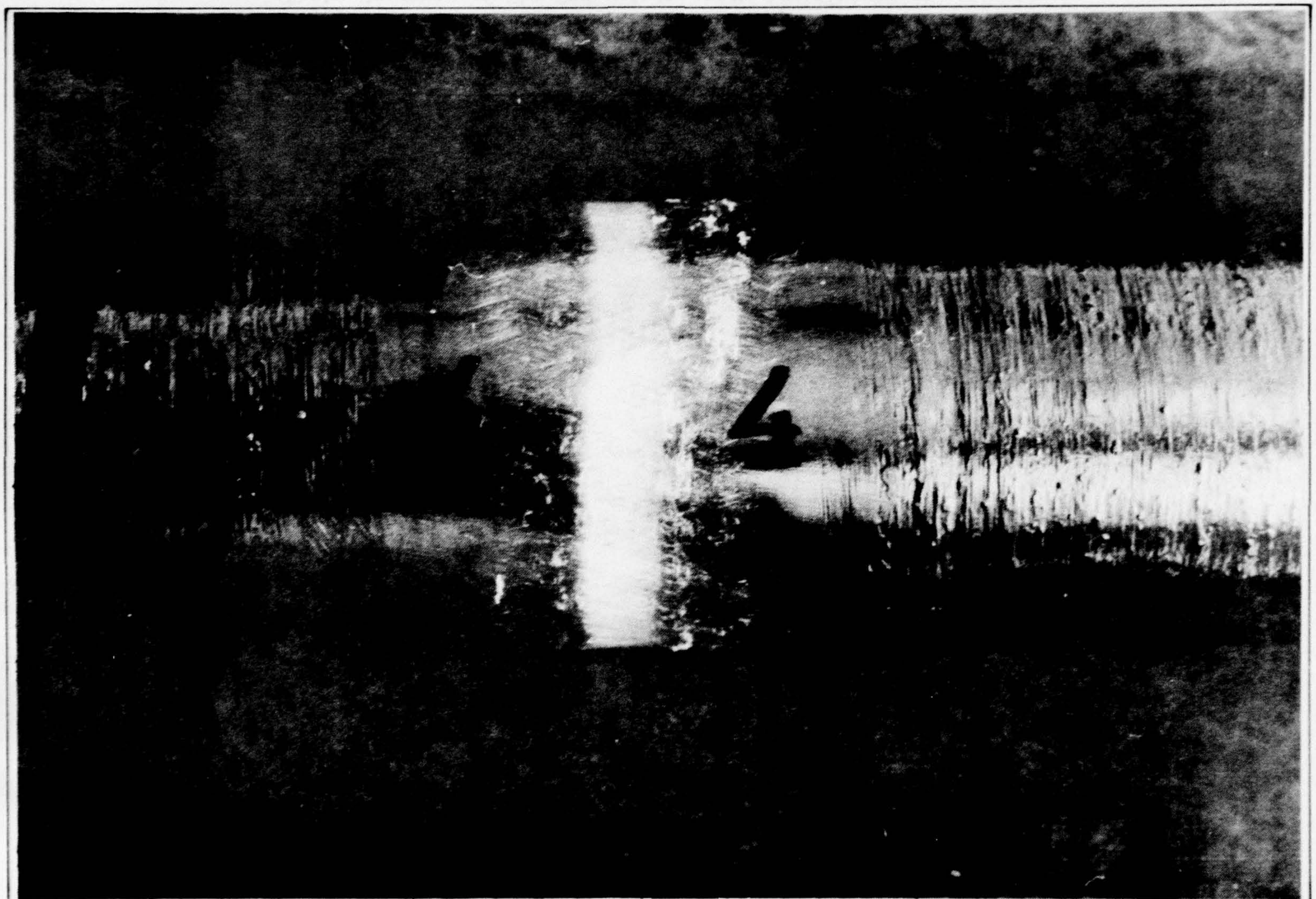


DESIGN TYPE IVb - Integral ring design without holes. See Fig. 10 and impact results on page 13.

DESIGN TYPE A - Helix Ring Design - This shows the early design using a 1-1/2 in. ring and incomplete separation.



DESIGN TYPE B - Helix Sleeve Design - (Similar to design Type II except with a 3 in. sleeve. The separation is complete.)



View of Break-Away Joint (Helix Ring Joint, Design A) Showing Separated Windings of Overwound Tube After Sanding (See Detail B, Drawing F-F-8161, Page 35)

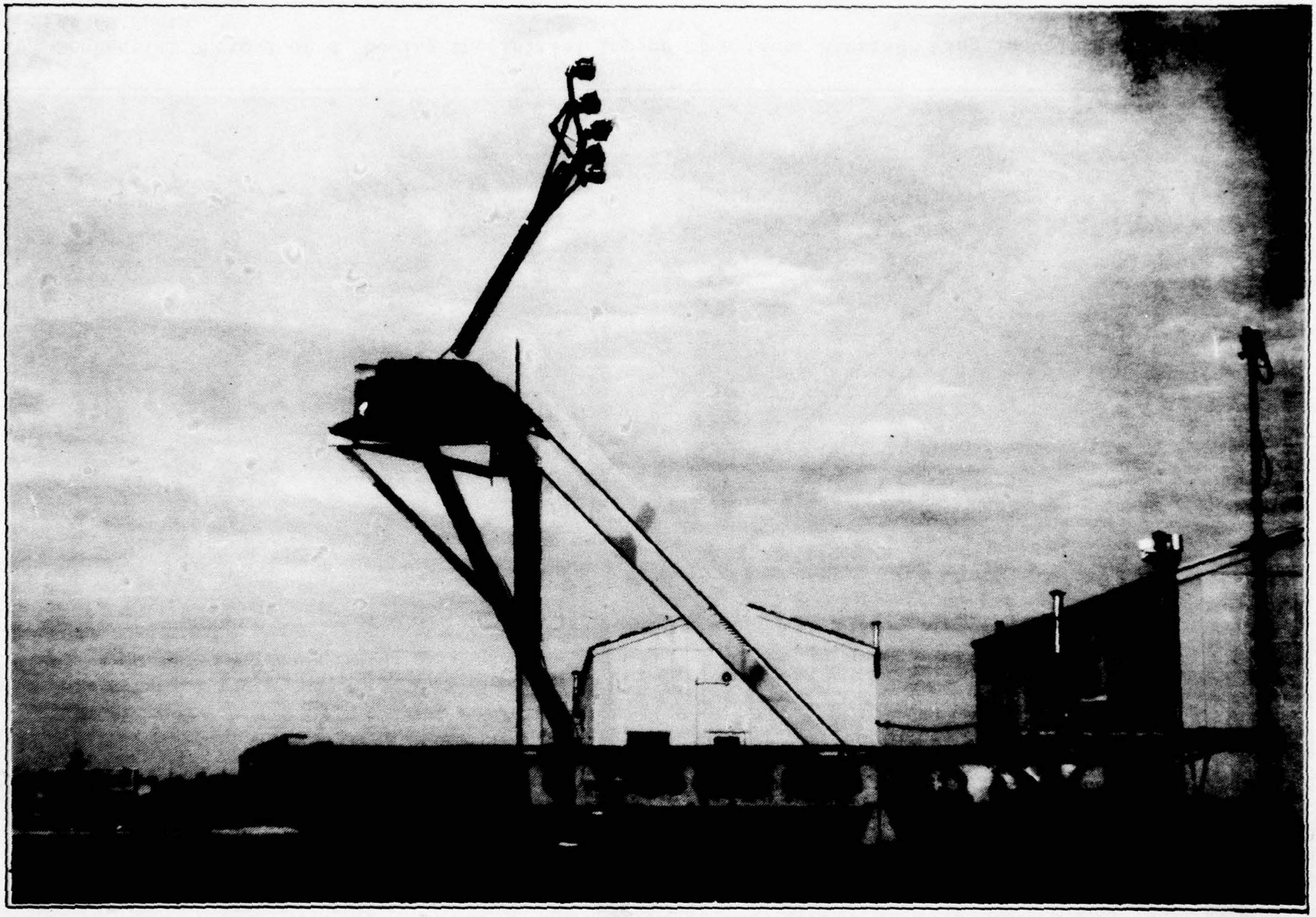
(Photo Courtesy of The Federal Aviation Administration)

Full Scale Impact Test Arrangement of A Prototype MG-20 Low Impact Resistant (LIR) Structure And the Wing of A Light Aircraft

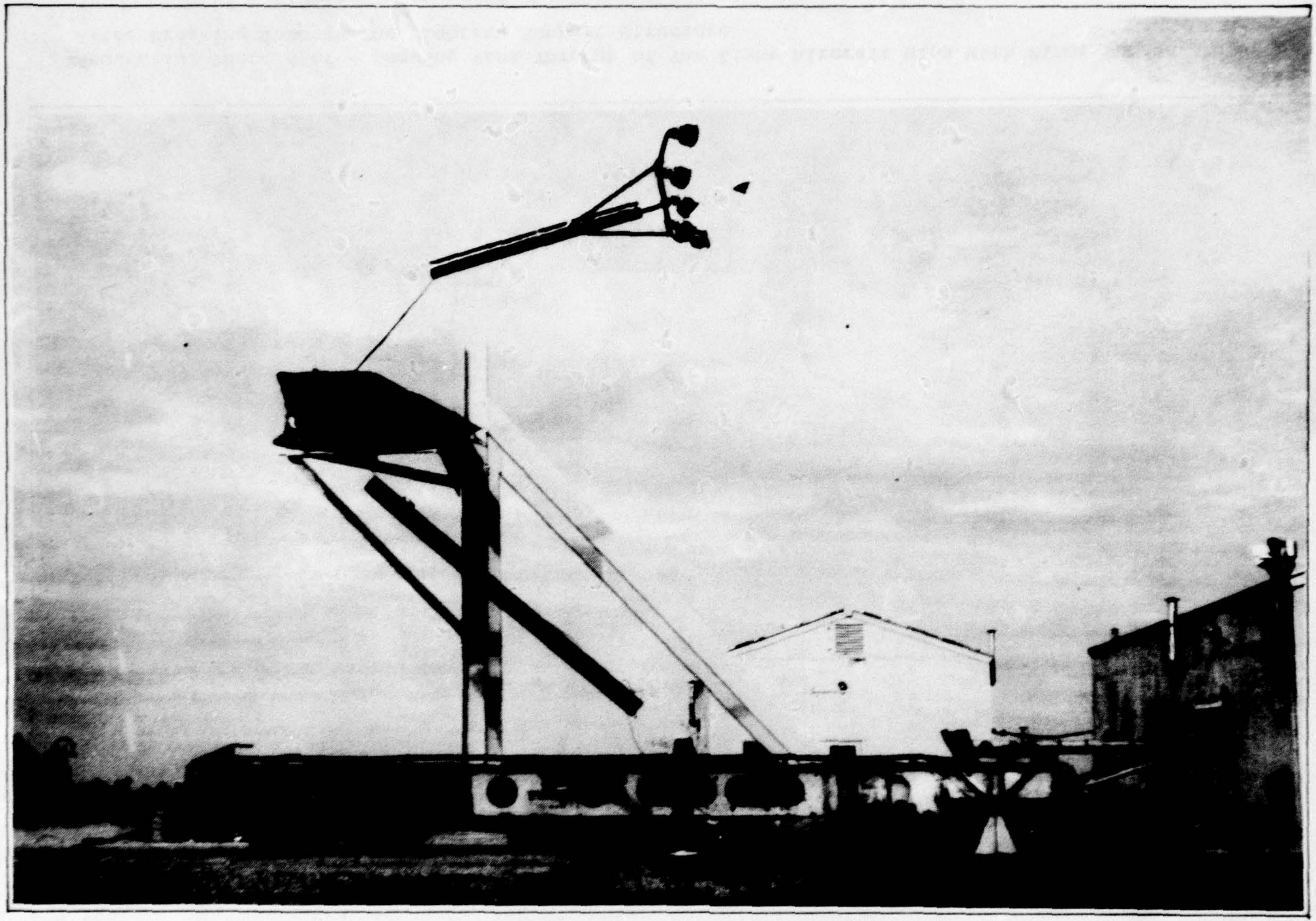
(Photo Courtesy of The Federal Aviation Administration)

Sequential Photo 1 of 4 Showing the Initial Impact of A Light Aircraft Wing Traveling At 69 Knots

(Photo Courtesy of The Federal Aviation Administration)

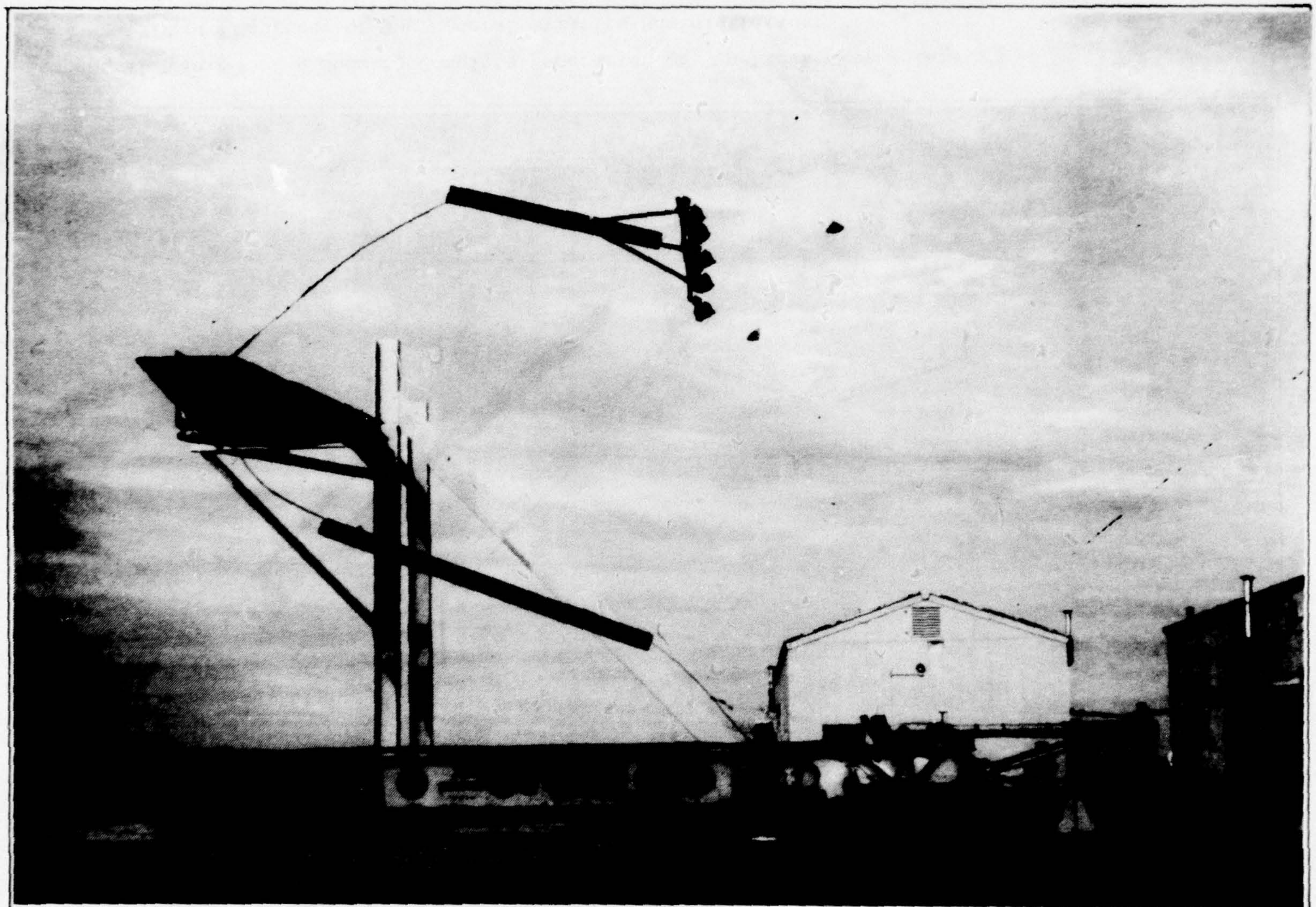


Sequential Photo 2 of 4 Showing Fracture Of The Break-Away Joints
(Photo Courtesy of The Federal Aviation Administration)



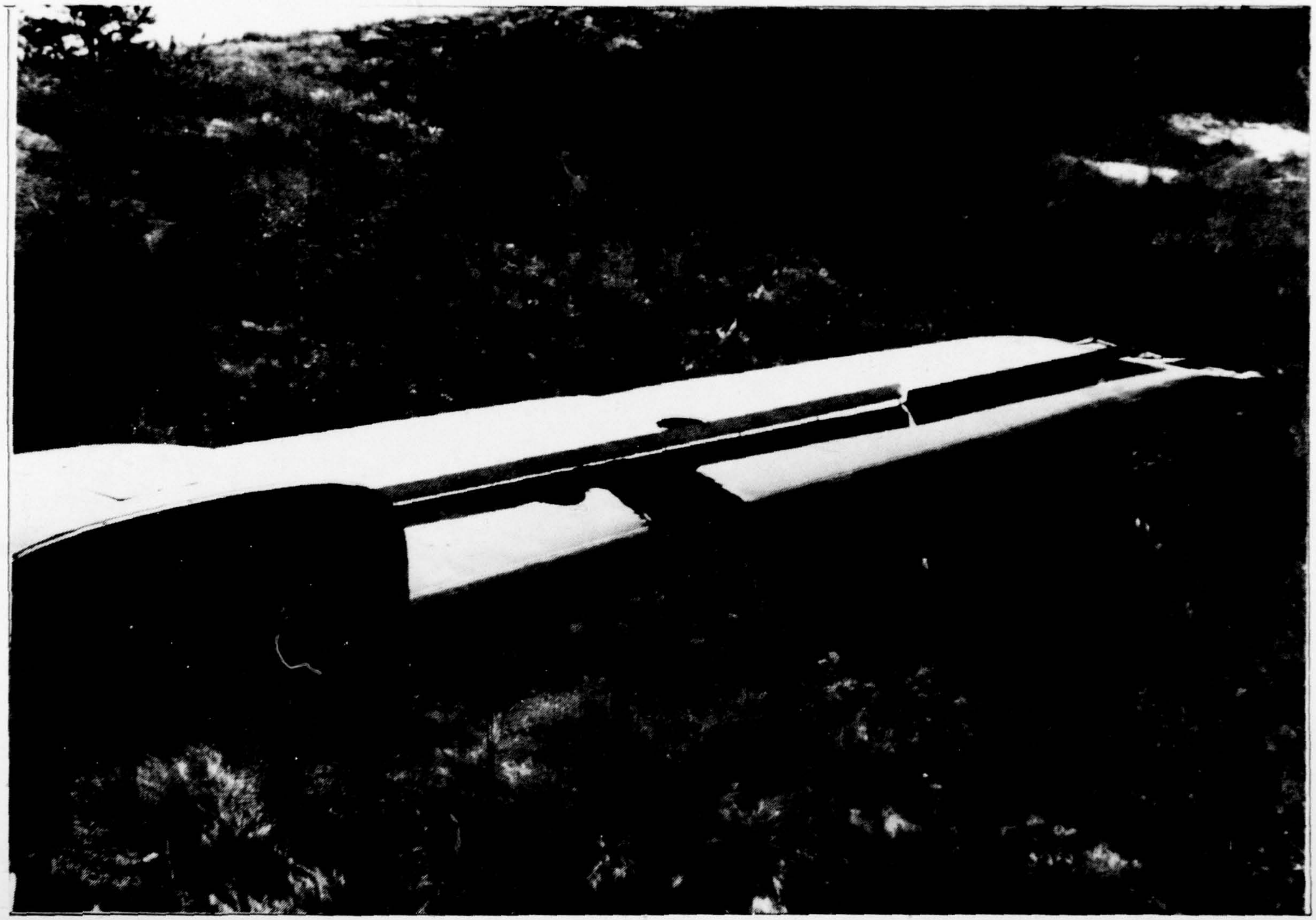
Sequential Photo 3 of 4 Showing Complete Separation of Two Break-Away Joints

(Photo Courtesy of The Federal Aviation Administration)



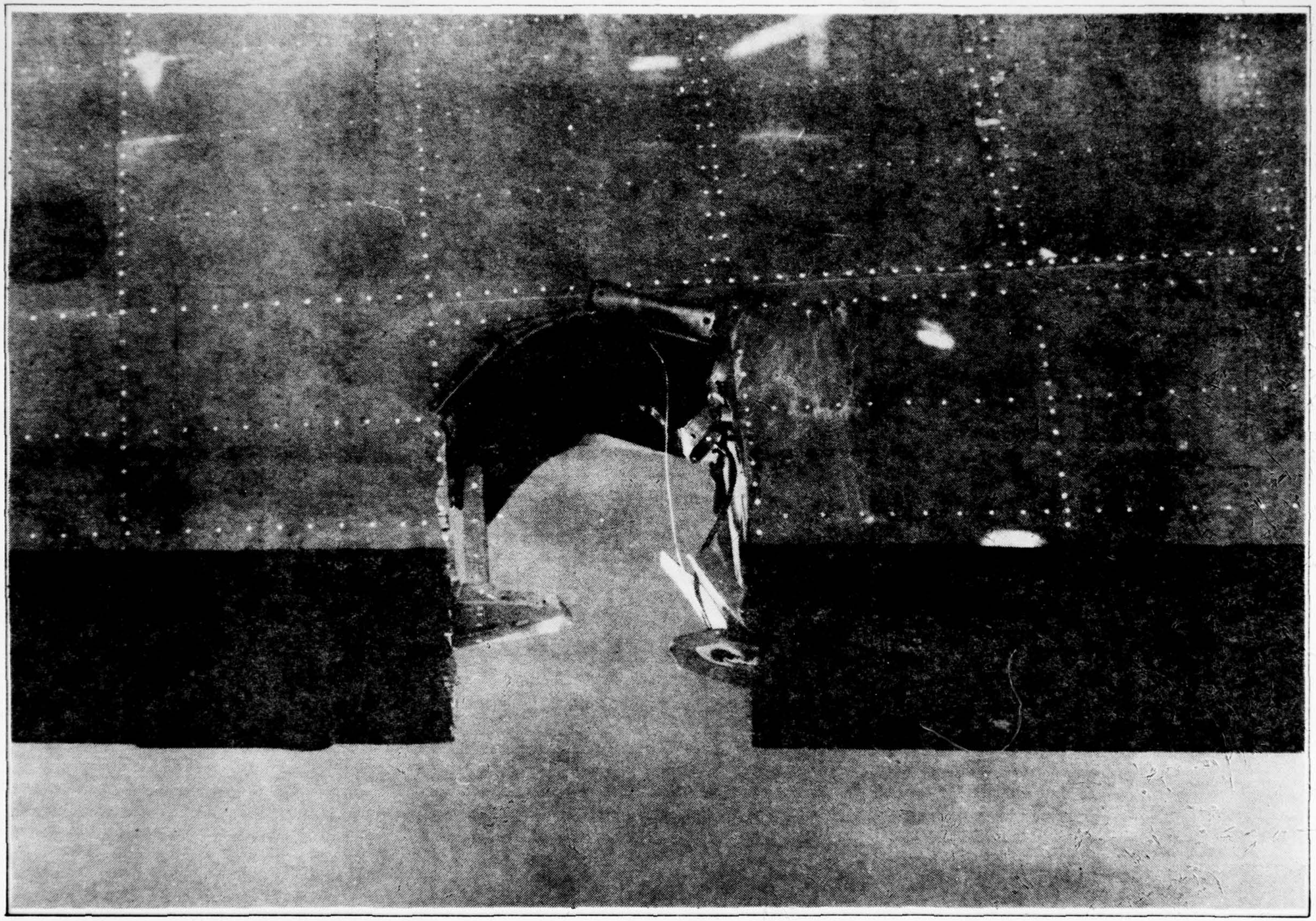
Sequential Photo 4 of 4 Showing Pass Through of The Light Aircraft Wing With Minor Damage After Breaking Through The Lighting Support Structure

(Photo Courtesy of The Federal Aviation Administration)



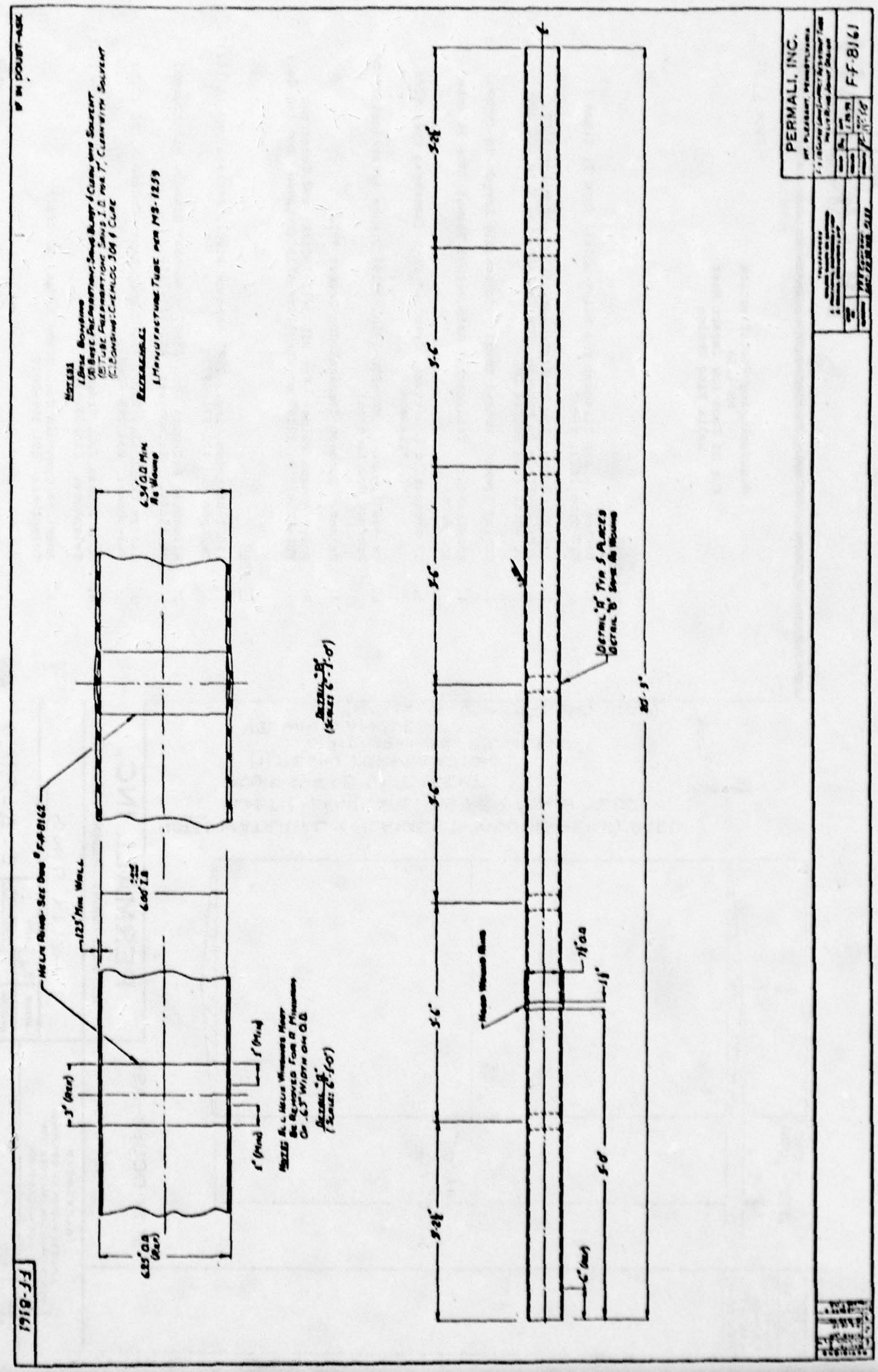
View of Damage To The Wing After Impact With The Prototype Low Impact Resistant Structure MG-20

(Photo Courtesy of The Federal Aviation Administration)



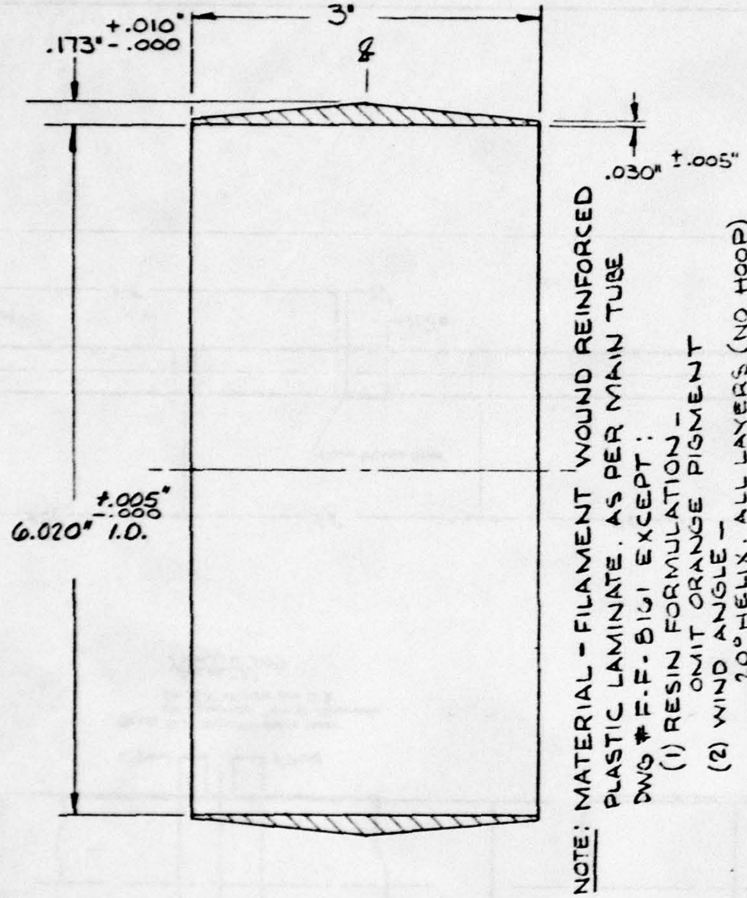
Closer View Of The Damaged Wing

(Photo Courtesy Of The Federal Aviation Administration)


F-F-8161
IF IN DOUBT—ASK
HELIX RING - SEE DWG # F-A-8162
3" (REF)
.125" MIN WALL
6.25" O.D. (REF)
6.00" I.D.
6.34" O.D. MIN AS WOUND
.5" (MIN)
NOTE: ALL HELIX WINDINGS MUST BE REMOVED FOR A MINIMUM OF .63" WIDTH ON O.D.
DETAIL "A" (SCALE: 6"-1'-0")
DETAIL "B" (SCALE: 6"-1'-0")
NOTES:
1. BASE BONDING
(A) BASE PREPARATION; SAND BLAST & CLEAN AND SOLVENT
(B) TUBE PREPARATION; SAND I.D. FOR 7", CLEAN WITH SOLVENT
(C) BONDING: CHEMLOC 304 & CURE
REFERENCE:
1. MANUFACTURE TUBE PER MS-1259
HOOP WOUND RING
6" (REF)
7½" O.D.
1½"
DETAIL "A" TYP 5 PLACES
DETAIL "B" SAME AS WOUND
30'-3"
PERMALI, INC.
MT. PLEASANT, PENNSYLVANIA
F-F-8161

REVISIONS

1	B.H 5-31-79	6.020" +.005 -.000 I.D. WAS 6.010" ±.005" SEE DRN-487



IF IN DOUBT–ASK

PERMALI, INC.
MT. PLEASANT. PENNSYLVANIA

HELIX RING

TOLERANCES
(UNLESS SHOWN ON DRAWING)
1. FRACTIONAL DIMENSIONS ± 1/64"
2. DECIMAL DIMENSIONS ± .010"

ORDER NO.		DRAWN	BH
		CHECKED	
REFERENCE	F.A.A TOWER (F-F-8161)	APPROVED	

DATE 1-29-79 SCALE FULL F-A-8162

PERMALI Incorporated
north american headquarters

Manufacturing Specification
MS-1259
For 20 Foot Low Impact Mast
Helix Ring Design

A. Material

1. Roving: Glass Filament per MIL-R-60346, Type I, Class I. PPG Type 1062, 8-end

2. Resin: Epoxy, low pressure laminating per MIL-R-9300, Type I, Grade 0, Form B. Dow Chemical Co. Type DER 330 or equal (see Source 2)

3. Curing Agent: Methyl Tetrahydrophthalic Anhydride (MTHPA)

4. Accelerator: Tridimethyl Aminomethyl Phenol (DMP 30 Rohm and Haas)

5. UV Protective Additive: Cyasorb* UV-9 (American Cyanimid)
*Trademark

6. Orange Pigment: FED-STD-595A, 12197 Orange (Plasticolor Inc. Product No. ED-6256)

7. Primer: Hughson Chemical Co. Primer 9922

8. Polyurethane Paint: Per MIL-C-81773C(AS) and Color per FED-STD-595A, 12197 or Chemglaze A871 (Hughson Chemical Co.)

B. Sources

1. PPG Industries, Inc., 2987 Babcock Blvd., Pittsburgh, PA 15237 Telephone: 412/931-0975

2. Allegheny Solvents, Box 15597 - Montour Branch, Pittsburgh, PA 15244. Telephone: 412-923-2570

3. Lindau Chemicals, Inc., 750 Granby Lane, Columbia, SC 29202 Telephone: 803/799-6863

4. Rohm & Haas Co., Independence Mall West, Philadelphia, PA 19105 Telephone: 215/592-3000

5. American Cyanimid Co., Bound Brook, NJ 08805 Telephone: 201/356-2000

p. o. box 718, mount pleasant, pennsylvania 15666 □ 412/547-4581 □ telex 866-666

Sources (cont'd)

6. Plasticolor, Inc., P. O. Box 816, Ashtabula, OH 44004
Telephone: 216/997-5137

7. Hughson Chemical Co., 2000 West Grandview Av., Erie, PA 16512
Telephone: 814/868-3611

8. Hughson Chemical Co., 2000 West Grandview Av., Erie, PA 16512
Telephone: 814/868-3611

C. Manufacturing

1. Set-Up

a. Resin System Expressed as Percent by Weight (PBW)

	Helix Ring	L.I.R. Tube
Epoxy	55.04	54.44
Hardener	44.03	43.55
Accelerator	.55	.54
U.V. Adder	.38	.38
Pigment	-----	1.09
Total	100.00	100.00

b. Band Density 154 Ends/Inch Helix: 96 Ends/Inch Hoop

c. Winding

1. 20° Helix - 3 Layers
2. 1" Pitch Hoop - 1 Layer

d. Curing - 3 Hrs. @ 80°C and 3 Hrs. @ 135°C

e. Finishing

1. Helix Ring: Machine to Drawing #F-A-8162
2. L.I.R. Tube:

(a) Machine O.D. to Drawing #F-A-8161
(b) All holes and cut edges shall be coated with the original resin
(c) Coat all exposed surfaces with one (1) coat of epoxy primer (Material #7) then one (1) coat of Polyurethane (Material #8)

Note: Both coatings can be sprayed or brushed

(d) All surfaces to be bonded together shall be roughened and cleaned with solvent before bonding

D. Requirements

1. Glass to Resin Ratio: 80/20 by Wgt.

2. Barcol Hardness: 55 to 65

3. Flexural Moment Capacity: 50,000 to 130,000 Inch Pounds
Test Method per PP 6.1, Page 9 and Fig. 11, Page 19

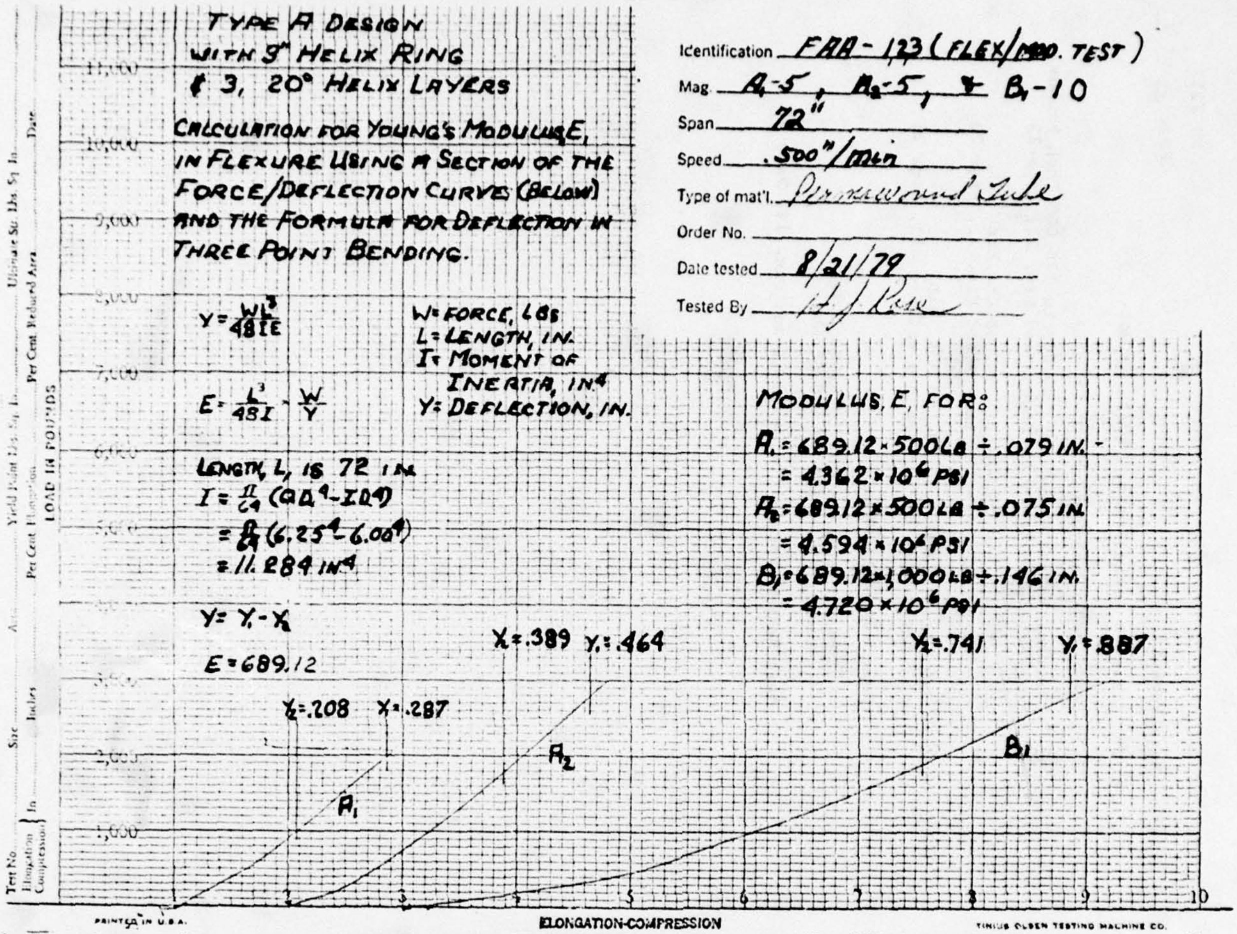
4. Compressive Load Capacity: 35,000 Lbs.Min.
Test Method per PP 6.2, Page 9 and Fig. 12, Page 20

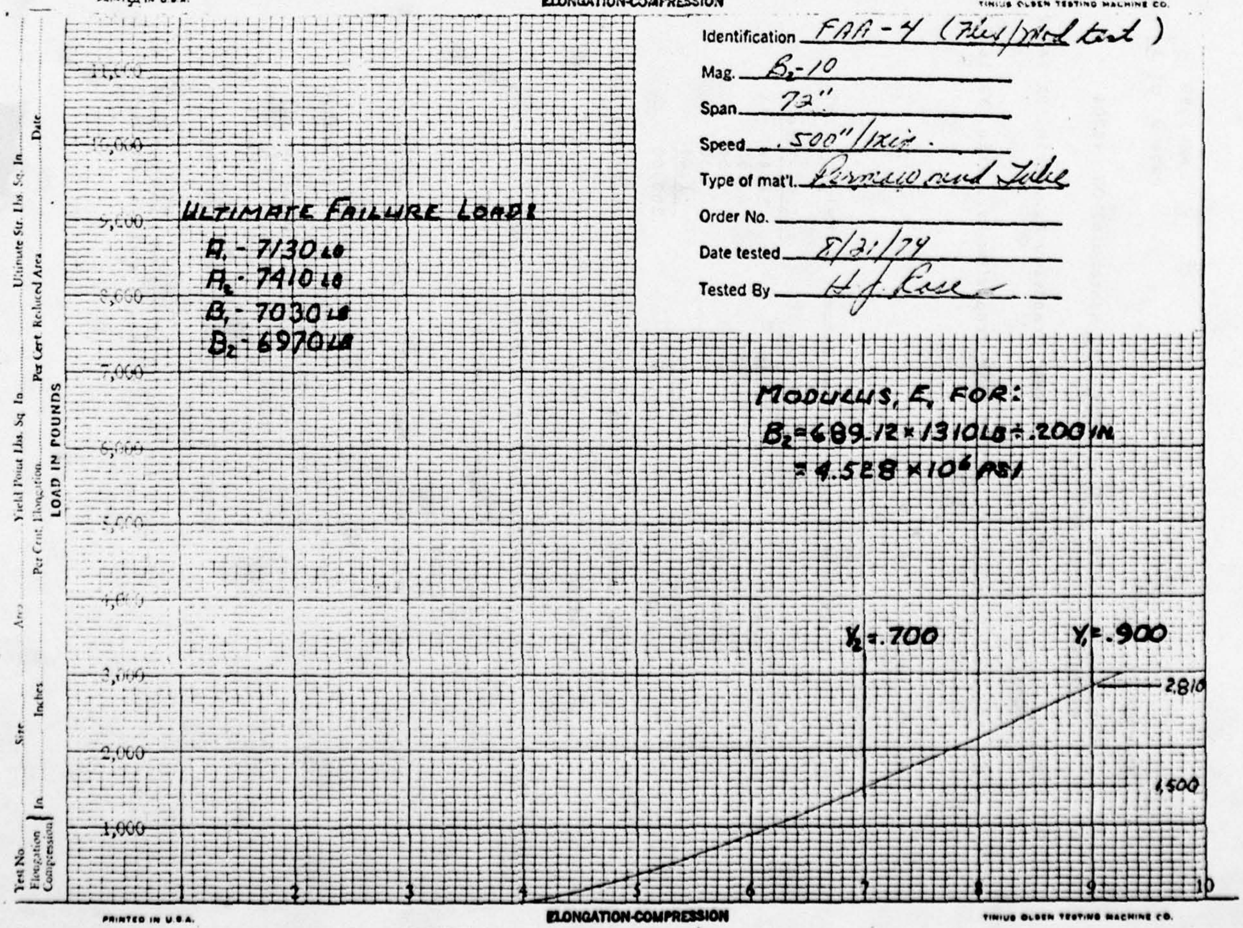
5. Shear Load Capacity: 14,000 Lbs. Min.
Test Method per PP 6.3, Page 9 and Fig. 13, Page 21

6. Impact Resistance:

Peak Force - 4,000 to 6,000 Lbs.
Energy - 540 to 690 Ft.Lbs.

Test Method per PP 6.4, Page 10 and Fig. 14, Page 22


TYPE A DESIGN
WITH 5" HELIX RING
3, 20° HELIX LAYERS
CALCULATION FOR YOUNG'S MODULUS E, IN FLEXURE USING A SECTION OF THE FORCE/DEFLECTION CURVES (BELOW) AND THE FORMULA FOR DEFLECTION IN THREE POINT BENDING.
$Y = \frac{WL^3}{48IE}$
W = FORCE, LBS
L = LENGTH, IN.
I = MOMENT OF INERTIA, IN^4
Y = DEFLECTION, IN.
$E = \frac{L^3}{48I} \cdot \frac{W}{Y}$
LENGTH, L, IS 72 IN.
$I = \frac{\pi}{64}(OD^4 - ID^4)$
$= \frac{\pi}{64}(6.25^4 - 6.00^4)$
$= 11.284\ IN^4$
$Y = Y_1 - Y_2$
E = 689.12
Identification FAA-123 (FLEX/MOD. TEST)
Mag. A_1-5, A_2-5, & B_1-10
Span 72"
Speed .500"/min
Type of mat'l. Permawound Tube
Order No.
Date tested 8/21/79
Tested By H J Rose
MODULUS, E, FOR:
A_1 = 689.12 × 500 LB ÷ .079 IN.
$= 4.362 \times 10^6$ PSI
A_2 = 689.12 × 500 LB ÷ .075 IN
$= 4.594 \times 10^6$ PSI
B_1 = 689.12 × 1,000 LB ÷ .146 IN.
$= 4.720 \times 10^6$ PSI
Y_2=.208 Y_1=.287
Y_2=.389 Y_1=.464
Y_2=.741 Y_1=.887
A_1
A_2
B_1
LOAD IN POUNDS
1,000
2,000
3,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
1 2 3 4 5 6 7 8 9 10
PRINTED IN U.S.A.
ELONGATION-COMPRESSION
TINIUS OLSEN TESTING MACHINE CO.


Identification FAA-4 (Flex/Mod test)
Mag. B_2-10
Span 72"
Speed .500"/min.
Type of mat'l. Permawound Tube
Order No.
Date tested 8/21/79
Tested By H J Rose
ULTIMATE FAILURE LOADS
A_1 - 7130 LB
A_2 - 7410 LB
B_1 - 7030 LB
B_2 - 6970 LB
MODULUS, E, FOR:
B_2 = 689.12 × 1310 LB ÷ .200 IN
$= 4.528 \times 10^6$ PSI
Y_2=.700 Y_1=.900
2,810
1,500
LOAD IN POUNDS
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
1 2 3 4 5 6 7 8 9 10
PRINTED IN U.S.A.
ELONGATION-COMPRESSION
TINIUS OLSEN TESTING MACHINE CO.

SUMMARY OF EXHIBITS

Exhibit A is a report of impact tests filed by Dr. Roger G. Slutter of Lehigh University. These are results of tests done on the original V-Notch design (see Fig. 6, page 14).

Exhibit B is a report of impact tests filed by Dr. Roger G. Slutter of Lehigh University. These are the results of tests done on the preliminary concepts of the break-away designs (see Figures 7, 8, 9 and 10 on pages 15, 16, 17 and 18).

Exhibit C is a report of impact tests filed by Dr. Roger G. Slutter of Lehigh University. These are results of the two optimized concepts, Design A and Design B.

Exhibit D contains the recordings of shear tests on the preliminary concept designs.

Exhibit E contains the recordings of flexure tests on the preliminary concept designs.

Exhibit F is a copy of FAA drawing D-6155-1 which illustrates the total airport lighting system support structures for MG-20, MG-30, and MG-40.

Exhibit G is a report of impact tests filed by Dr. Roger G. Slutter of Lehigh University. These are results of tests on four samples of the final helix ring design (see drawing F-F-8161, Detail B, page 35).

Exhibit A

FRITZ ENGINEERING LABORATORY
Lehigh University

File 200.78.487.1

Sheet 1 of 1

Date 9/28/78

Party C.H.
H.S.
R.G.S.

Approved [signature]
Director - Operations

Subject Preliminary Impact Tests of Notched Fiberglass Tubes

Specimen No.

Mr. R. Eshbaugh
Permali Inc.
P. O. Box 718 Bridgeport St. Ext.
Mount Pleasant, Pa. 15666

Tube Specimen No.	Aluminum Plug Length	Average Deformation of Plugs	Energy Absorbed by Plugs (ft.-lbs.)	Energy Absorbed by Tube (ft.-lbs.)	Remarks
1	1.172 1.222 1.133 1.193	0.320	2000	2592	All plugs were 1.500" long at start of test
2	1.227 1.224 1.176 1.147	0.306	1950	2642	Total Energy for Tests 1 and 2 was 4592 ft.-lbs.
1600 lb. weight removed and 408 lb. weight was installed					
3	--	0	0	2695	Tube crushed against track on both tests 3 and 4 and weight did not reach aluminum plugs
4	--	0	0	2980	

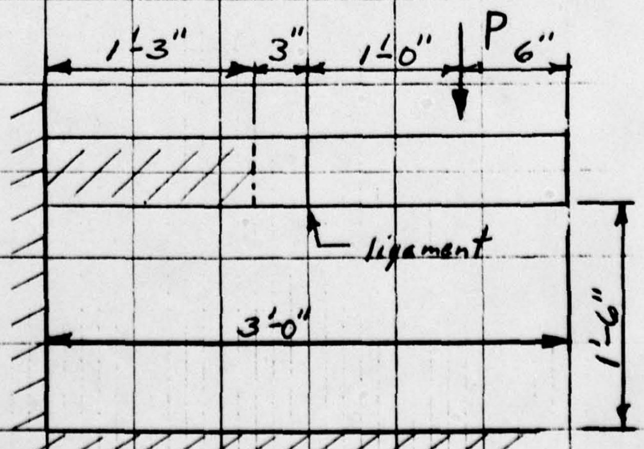


Exhibit A

200.78.487.1

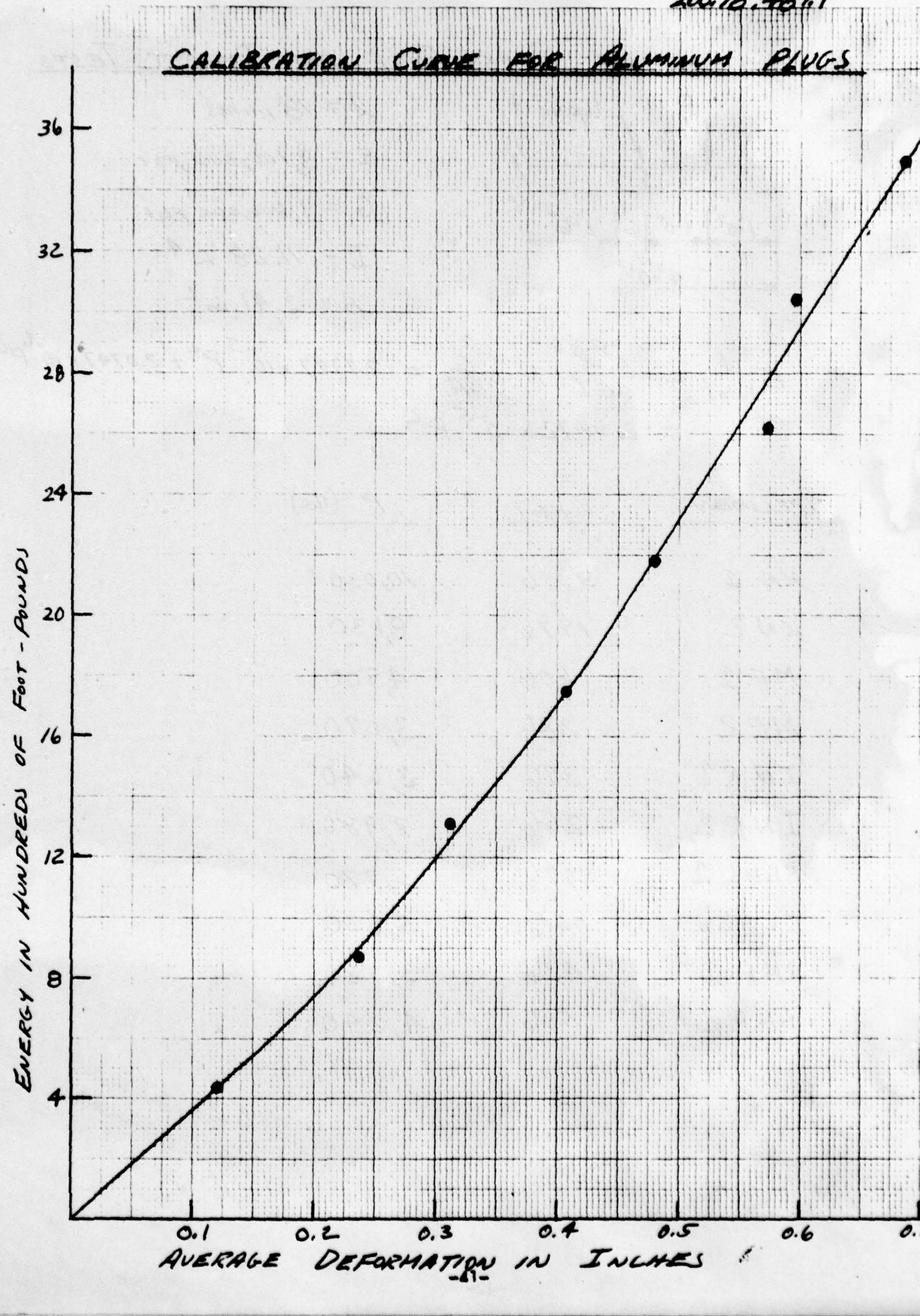
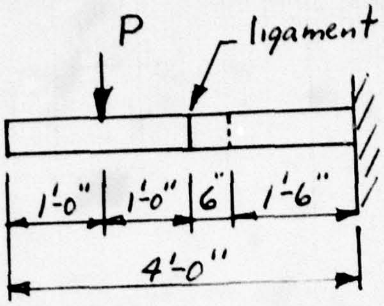


Exhibit A 200.78.487.1

CALCULATION OF PEAK FORCE FOR IMPACT TESTS



$l = 18$ inches

$E = 3,100,000$ psi

$G = 1,800,000$ psi

$I = 11.28 \text{ in}^4$

$A = 2.41 \text{ in}^2$

$$E_{total} = \frac{P^2 l^3}{6EI} + \frac{P^2 l}{2GA} = 2.7797 \times 10^{-5} P^2 + 2.0747 \times 10^{-6} P^2$$

$$= 2.9872 \times 10^{-5} P^2$$

SPECIMEN	E_{total}	P (lbs.)
KN 1	3006	10,030
KN 2	1976	8,130
MF 1	606	4,500
MF 2	286	3,090
INR 1	396	3,640
INR 2	266	2,980
SLHL 1	996	5,770
SLHL 2	946	5,630
SHP 1	426	3,780
SHP 2	536	4,240

LEHIGH UNIVERSITY
BETHLEHEM, PENNSYLVANIA 18015
TELEPHONE (215) 691-7000

DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY #13

200.78.487.1 November 22, 1978

Mr. R. Eshbaugh
Permali Inc.
P. O. Box 718 Bridgeport St. Ext.
Mount Pleasant, Pa. 15666

Re: Impact Tests of Fiberglass Tubes

Dear Mr. Eshbaugh:

The preliminary impact tests made on 3 ft. long tubes in September are reported on a separate data sheet because the testing procedure for these tests was different from the tests made on the ten tubes tested on 11/3/78. The first two preliminary tests of the notched tubes were made using a 1600 lb. weight dropped from two feet above the tube. For these tests four aluminum plugs were required to arrest the weight after fracture of the tube. Following these tests it was decided to test with a smaller weight having a high velocity.

A 400 lb. weight with an 8 lb. tup was used for preliminary tests 3 and 4 and two aluminum plugs were used for arresting the weight after fracture. In these two tests the tubes crushed and jammed against the track of the drop weight machine. In order to correct the problems encountered in these tests, the length of the test tubes was changed to 4 ft., the lower section of track was removed, and a larger tup with a larger striking radius was made.

The energy absorbed by the four preliminary test tubes in fracturing were 2592, 2642, 2695, and 2890 ft.-lbs. From observations made during these and subsequent tests, it could be observed that the total energy absorbed by the tubes consists of three parts. These are (1) energy to deflect the tube, (2) energy to deform the cross section, and (3) energy to fracture the ligament. There is no way of separating these components, but it could be observed in the preliminary tests that all three components were of significant magnitude.

The test procedure used in the ten tests conducted on 11/3/78 tended to reduce the cross section deformation component by reducing this deformation to essentially elastic rather than plastic deformations except for possibly

KN 1 and KN 2. For the other eight specimens the bending and fracture components predominate.

The deformation of the aluminum plugs used to arrest the weight after fracture provide the only means of measuring the total energy absorbed by the tubes. The enclosed calibration curve for the aluminum plugs was used to determine the energy absorbed in fracture of the tubes. Aluminum plugs used for the preliminary tests were from a different lot having a slightly different calibration curve. The energy absorbed by each tube is given in the next to last column of the data sheet.

During the tests signals were recorded on a storage oscilloscope from an accelerometer mounted on the weight. Examples of these recordings are enclosed for some of the tests. These recordings were only partially successful because resistance force offered by the tubes were either very small in the case of some tests or very large when the weight was arrested. The large resistance of the aluminum plugs caused the signals to go out of range while the small resistance offered by some tubes barely produced a signal. Since in all tests the energy absorbed by bending of the tubes was relatively large, the resistance produced at initial contact of the weight with the tube was small and did not register. Basically the "blip" recorded as the tube was hit indicates a change in acceleration of the weight. By the equation F = ma the force encountered is proportional to the acceleration registered on the graphs. However, these are probably only a qualitative picture of the event and it is difficult to obtain the force because the response is not linear over the range of forces involved.

The two graphs for preliminary tests 2 and 4 indicate that the accelerometer went out of range during the event because the gain was too high. The graphs for MF 2, INR 2 and SLHL 2 show the event but the signal went out of range when the aluminum plugs were encountered. The height of the event signal for contact with the tube is recorded in range. The vertical scale for SLHL 2 is twice that for the other two. The amplitude must be reduced to half for comparison with MF 2 and INR 2.

The best method for obtaining value for the maximum force encountered for each test is to use equivalent deflection equated to total energy absorbed. This method ignores deformation of the cross section as being negligible in

comparison to the other two components. The energy absorbed in fracture is considered in terms of equivalent deflection. This method may slightly overestimate the force for KN 1 and KN 2 where deformation of the cross section may be significant. Values for the other tests should be good estimates of the peak force. The effect of the ligaments on the deflections is not significant because the length of the ligament is small compared to the span length.

The total energy is equated to the energy absorbed in flexure plus the energy absorbed in shear by the following equation.

$$\text{Total Energy} = \frac{P^2 \ell^3}{6\ E\ I}\ \text{(flexure)} + \frac{P^2 \ell}{2GA}\ \text{(shear)}$$

where P is the maximum force. The enclosed computation sheet gives the properties used for computations and the resulting force for each of the ten tests conducted on 11/3/78. These values should agree reasonably well with values obtained from your static tests.

Sincerely yours,

Roger G. Slutter

Roger G. Slutter
Professor of Civil Engineering
Director - Operations Division

RGS/df

Enclosures

Exhibit B

FRITZ ENGINEERING LABORATORY
Lehigh University

File 200.78.487.1
Sheet 1 of 1
Date 11/3/78
Party C.H.
H.S.
R.G.S.
Approved *Roger G. Slutter*
Director - Operations

Subject Impact Tests of Notched Fiberglass Tubes

Specimen No.

Mr. R. Eshbaugh
Permali Inc.
P. O. Box 718 Bridgeport St. Ext.
Mount Pleasant, Pa. 15666

Tube Specimen No.	Aluminum Plug Length (in.)		Average Deformation of Plugs (in.)	Energy Absorbed by Plugs (ft.-lbs.)	Energy Absorbed by Tube (ft.-lbs.)	Remarks
KN 1	1.342	1.356	0.151	540	3006	All plugs were 1.500" long at start of test
KN 2	1.152	1.093	0.275	1570	1976	
MF 1	0.906	0.894	0.600	2940	606	Total energy for each test was 3546 ft.-lbs.
MF 2	0.865	0.830	0.652	3260	286	
INR 1	0.866	0.869	0.633	3150	396	
INR 2	0.858	0.832	0.655	3280	266	4-1/4" holes drilled at ligament and 6" cut from end of tube
SLHL 1	0.957	0.965	0.539	2550	996	
SLHL 2	0.921	0.989	0.545	2600	946	
SHP 1	0.844	0.890	0.628	3120	426	
SHP 2	0.908	0.871	0.611	3010	536	

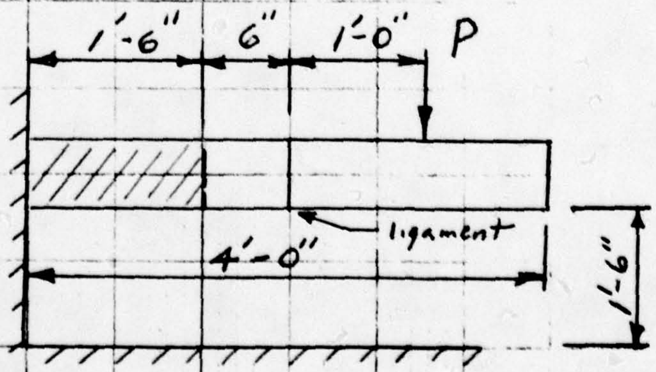


Exhibit C

LEHIGH UNIVERSITY
BETHLEHEM, PENNSYLVANIA 18015
TELEPHONE (215) 691-7000

DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY #13

200.78.487.1

December 14, 1978

Mr. Bob Eshbaugh
PERMALI, INC.
P. O. Box 718, Bridgeport Street Ext.
Mount Pleasant, Pa. 15666

Re: Impact Tests of Fiberglass Tubes

Dear Mr. Eshbaugh:

On December 7 the last group of tubes was tested using a smaller weight dropped from the same height as in the previous tests. Following the tests we made a new calibration run on aluminum plugs and we determined the exact weight of the impact weight. The corrections resulting from this check have been incorporated into the analysis. The energy absorbed by each tube is somewhat higher than the amount determined on the day of the test. We have found that whenever we changed the weight, it is necessary to run a new set of aluminum plug calibrations.

The high speed motion picture of all six tests have been sent to you under separate cover along with a few black and white photographs. The films are slightly under-exposed for dark areas due to the fact that the speed of the camera is approximately 1100 frames per second instead of 1000 frames per second.

The peak force values have been obtained from the energy equation as in the previous test. This data appears to correlate well with the data from the previous tests using the larger weight. However, you may be aware of differences in the test specimens that I am not considering.

Sincerely yours,

Roger G. Slutter

Roger G. Slutter
Professor of Civil Engineering
Director - Operations Division

RGS/df

Enclosures

Exhibit C

FRITZ ENGINEERING LABORATORY

Lehigh University

File 200.78.487.1

Sheet 1 of 1

Date 12/11/78

Party C.H. R.K.

Subject Final Impact Tests of Notched Fiberglass Tubes

Specimen No.

Permali Inc.
P. O. Box 718 Bridgeport St. Ext.
Mount Pleasant, Pa. 15666 Attn: Bob Eshbaugh

Approved Roger G. Slutter

Director - Operations

Tube Specimen	Aluminum Plug Length (in.)	Average Deformation of Plugs (in.)	Energy Absorbed by Plugs (ft.-lbs.)	Energy Absorbed by Tube (ft.-lbs.)	Remarks
HLRG-1	1.138 & 1.112	0.375	1180	582	All plugs were 1.500 in. long at start of test.
HLRG-2	1.138 & 1.137	0.363	1120	642	
SLHL-1	1.190 & 1.205	0.303	860	902	Total energy for all tests = 1762 ft.-lbs.
SLHL-2	1.188 & 1.235	0.289	810	952	
INR-1	1.075 & 1.113	0.406	1320	442	
INR-2	1.071 & 1.099	0.415	1360	402	

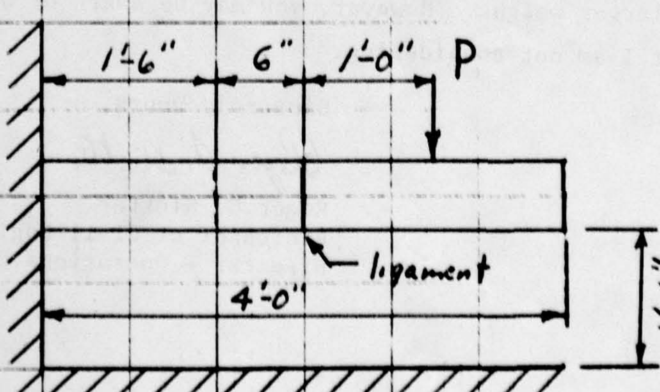


Exhibit C

FRITZ ENGINEERING LABORATORY
Lehigh University

File 200.78.487.1
Sheet 1 of 1
Date 12-11-78
Party C.H.
R.K.
Approved

Subject CALIBRATION OF ALUMINUM PLUGS WITH 217.7 LB. WEIGHT

Specimen No.

PERMALI, INC.
P.O. BOX 718
BRIDGEPORT STREET EXT.
MOUNT PLEASANT, PA. 15666

P.O. MP 14147

USE THIS CALIBRATION CURVE FOR TESTS DONE ON 12-7-78

ACTUAL WEIGHT = 217.7 LBS. (weighed after test)

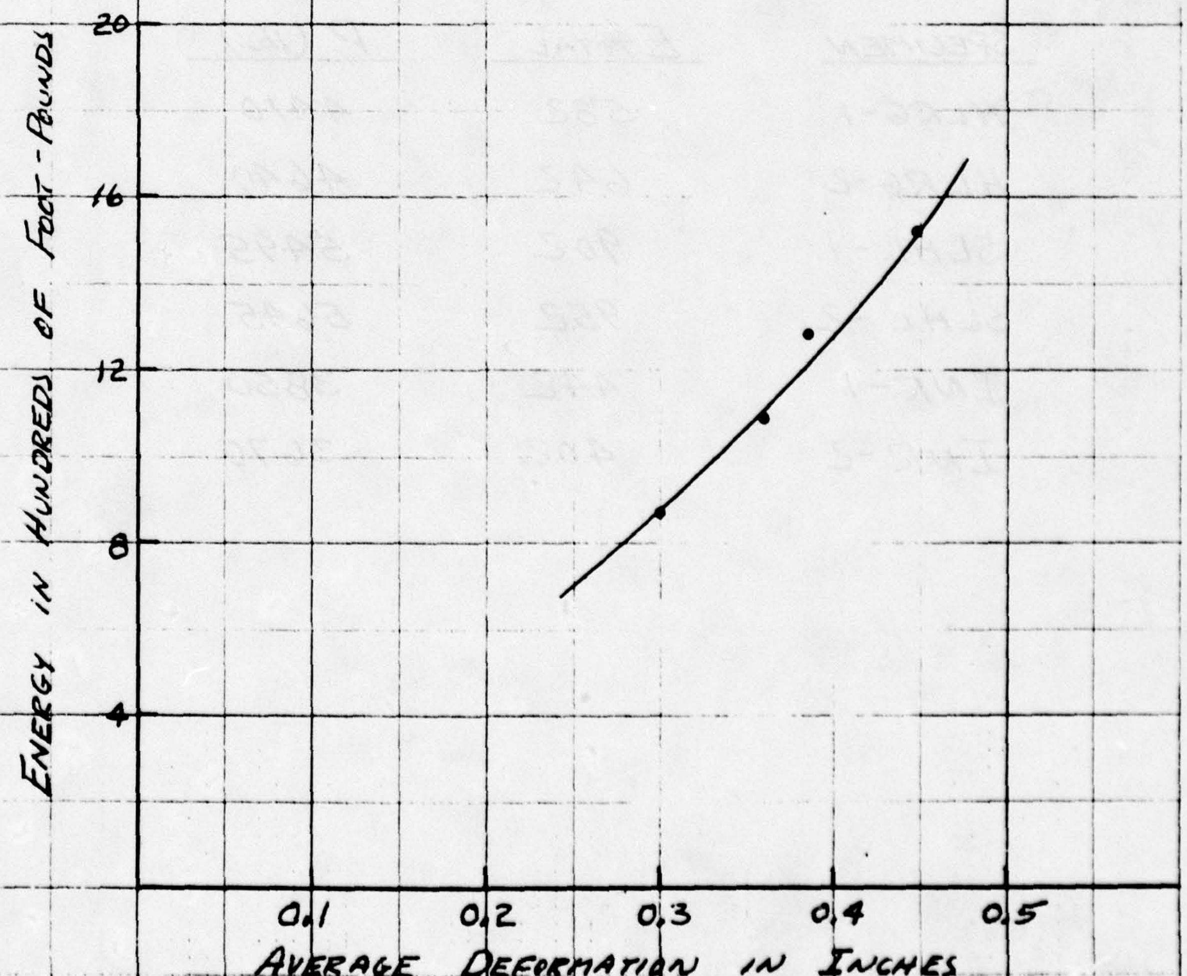
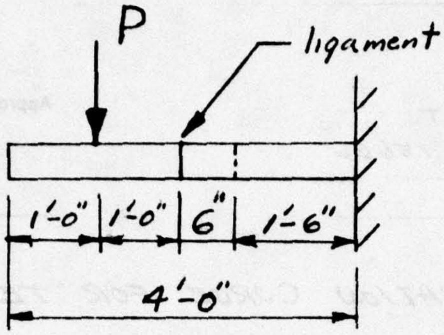


Exhibit C

CALCULATION OF PEAK FORCE FOR IMPACT TESTS MADE ON 12-7-78



$l = 18$ inches

$E = 3{,}100{,}000$ psi

$G = 1{,}800{,}000$ psi

$I = 11.28 \text{ in.}^4$

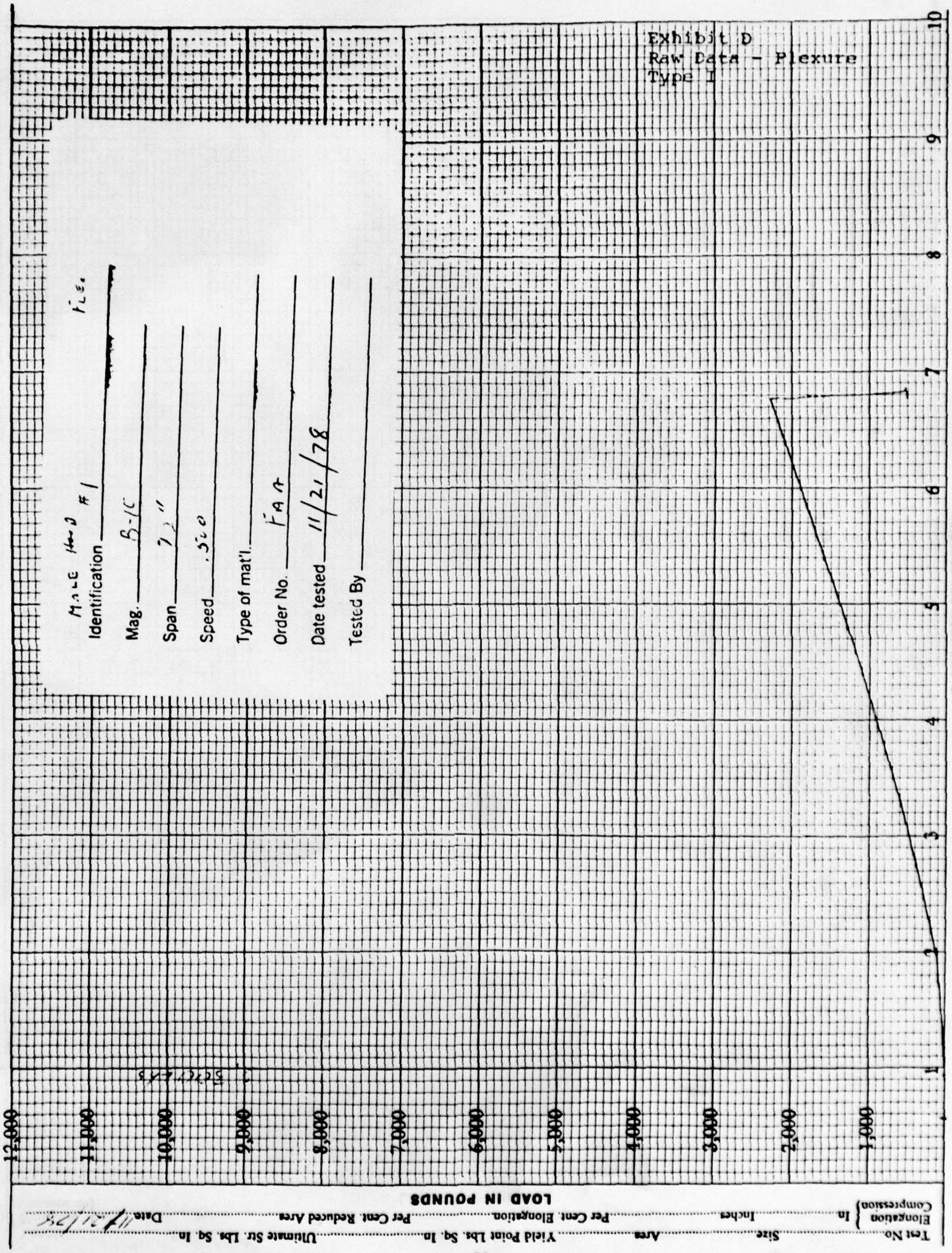
$A = 2.41 \text{ in.}^2$

$$E_{nergy\,(Total)} = \frac{P^2 l^3}{6EI} + \frac{P^2 l}{2GA}$$

$$= 2.9872 \times 10^{-5} P^2$$

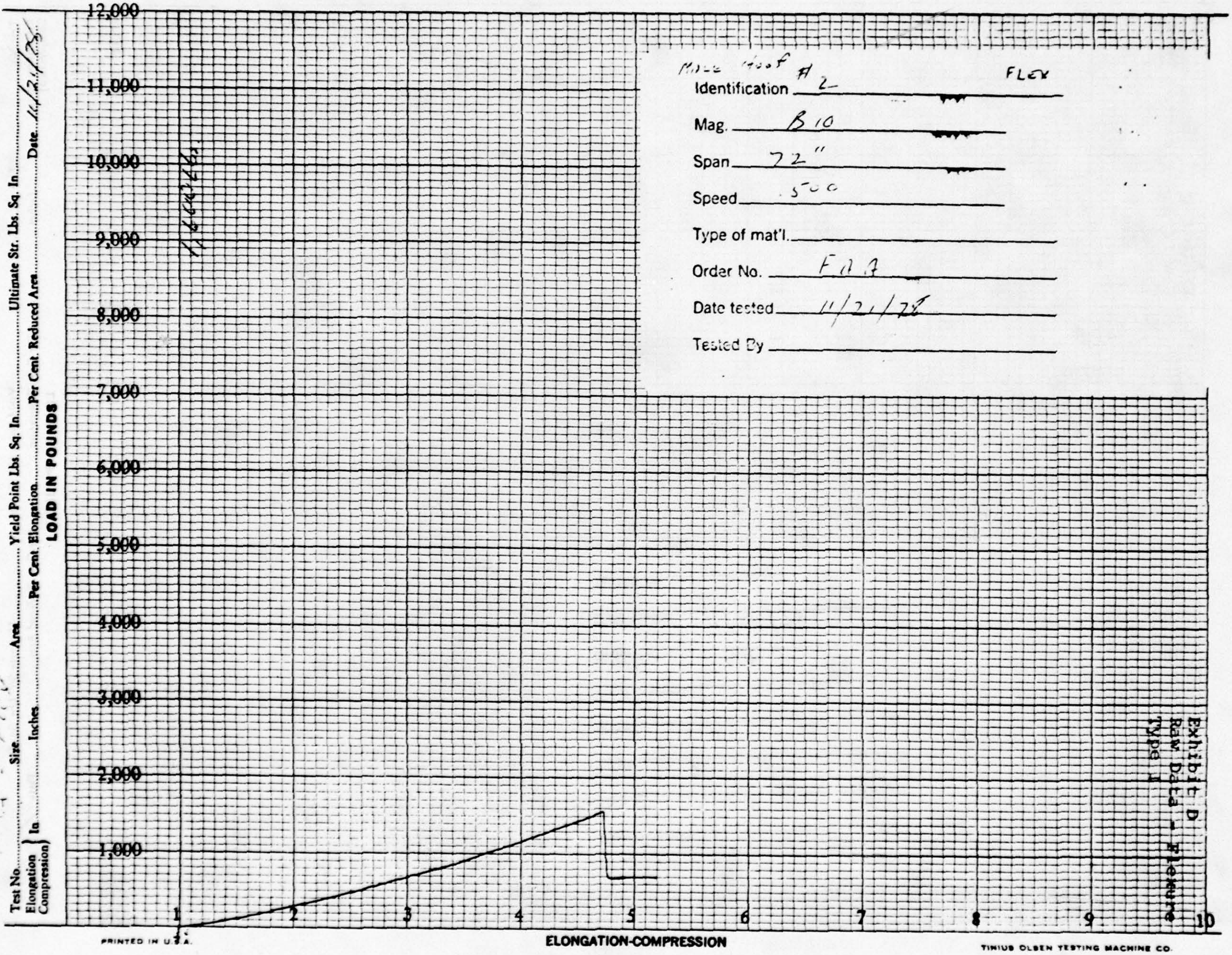
SPECIMEN	E_{TOTAL}	P (lbs.)
HLRG-1	582	4410
HLRG-2	642	4640
SLHL-1	902	5495
SLHL-2	952	5645
INR-1	442	3850
INR-2	402	3670

Exhibit D
Raw Data - Plexure
Type I



Test No. .... Size .... Area .... Yield Point Lbs. Sq. In. .... Ultimate Str. Lbs. Sq. In. ....

Elongation / Compression } In .... Inches .... Per Cent. Elongation .... Per Cent. Reduced Area .... Date 11/21/78



Mixed Woof #2 FLEX

Identification #2

Mag. B10

Span 72"

Speed 500

Type of mat'l.

Order No. FAA

Date tested 11/21/78

Tested By

PRINTED IN U.S.A.

TINIUS OLSEN TESTING MACHINE CO.

Exhibit D
Raw Data - Flexure
Type II

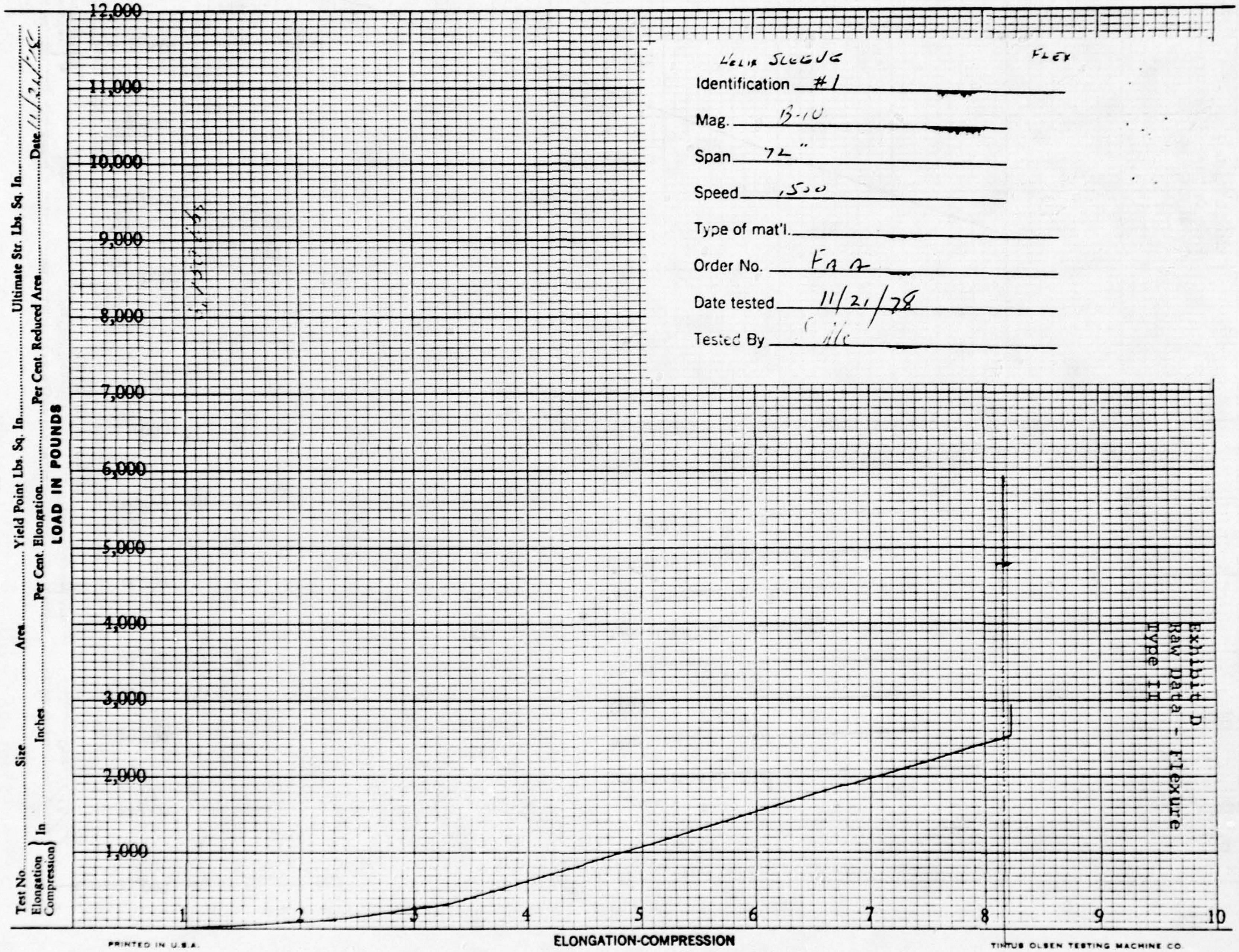
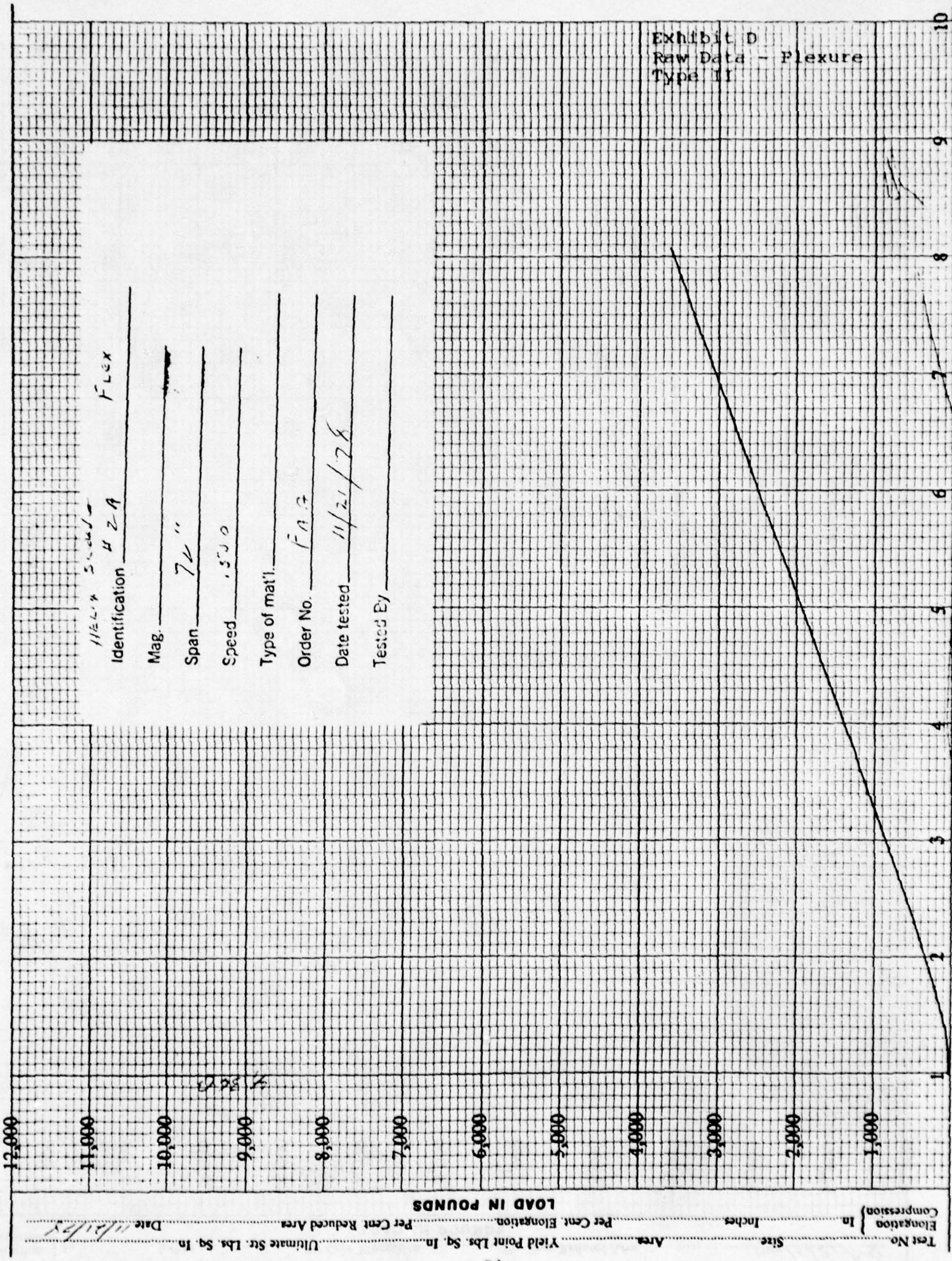


Exhibit D
Raw Data - Flexure
Type II



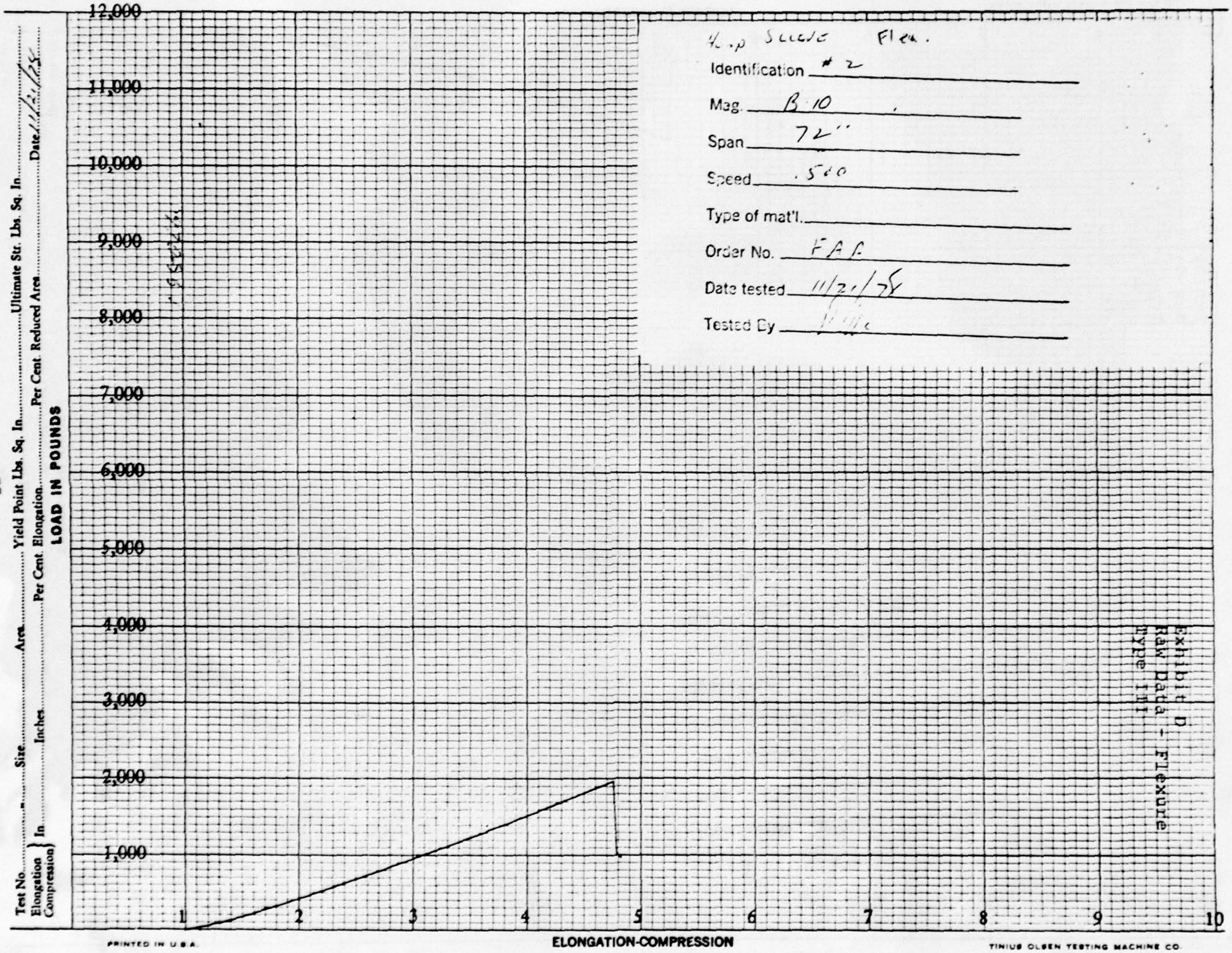


Exhibit D
Raw Data - Flexure
Type III

Exhibit D
Raw Data - Flexure
Type III

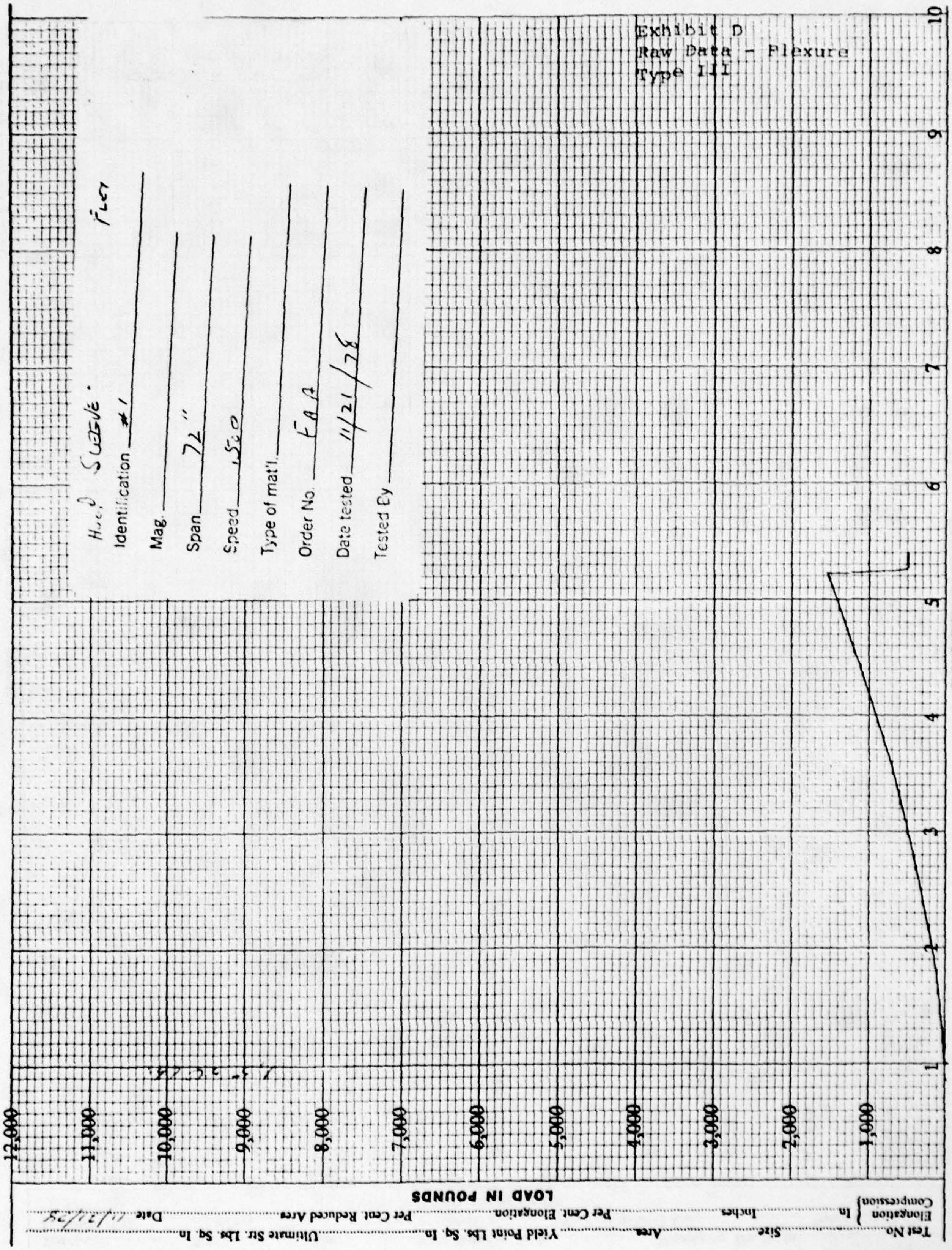


Exhibit D
Raw Data - Flexure
Type IV

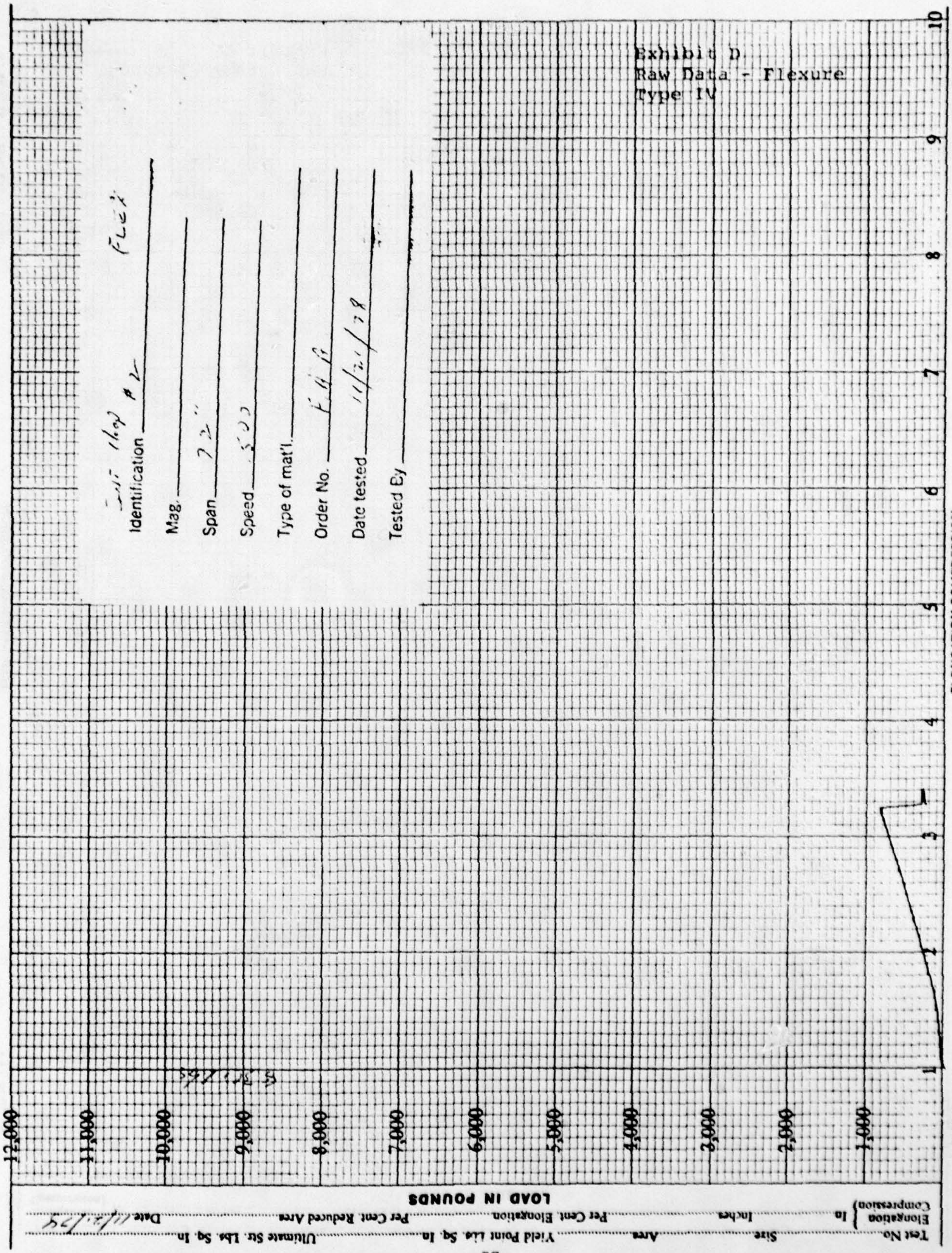


Exhibit D
Raw Data - Flexure
Type IV

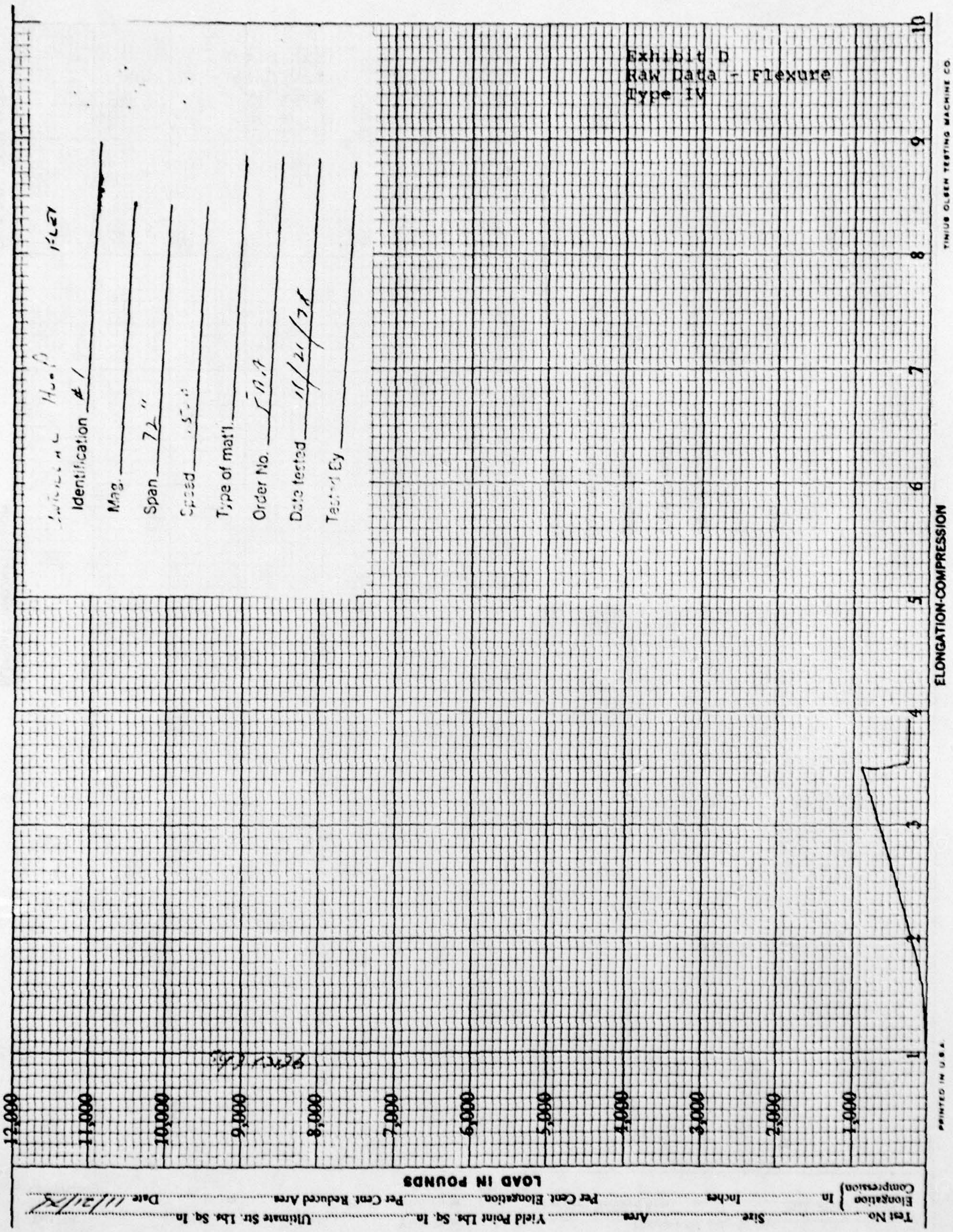
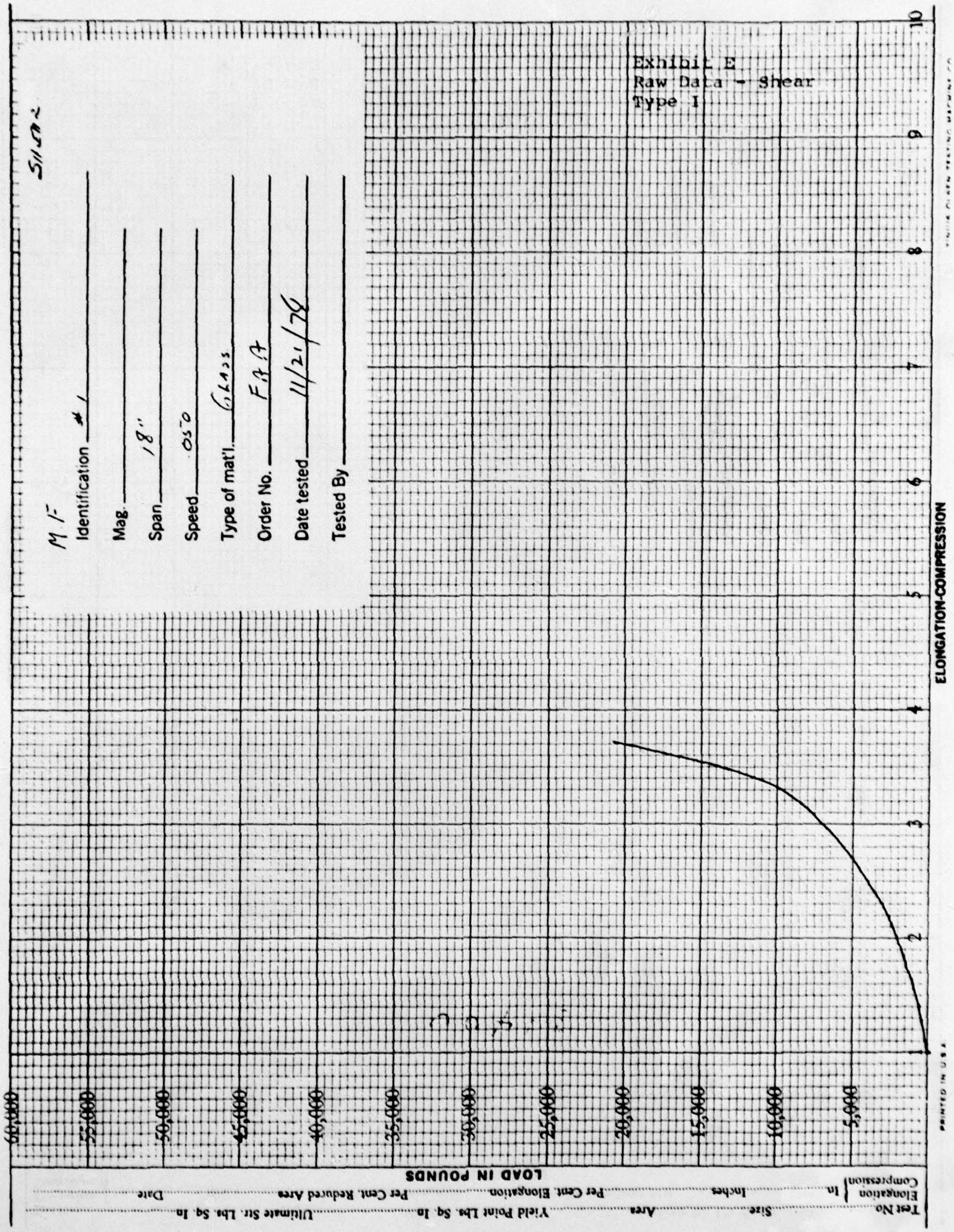


Exhibit E
Raw Data - Shear
Type I



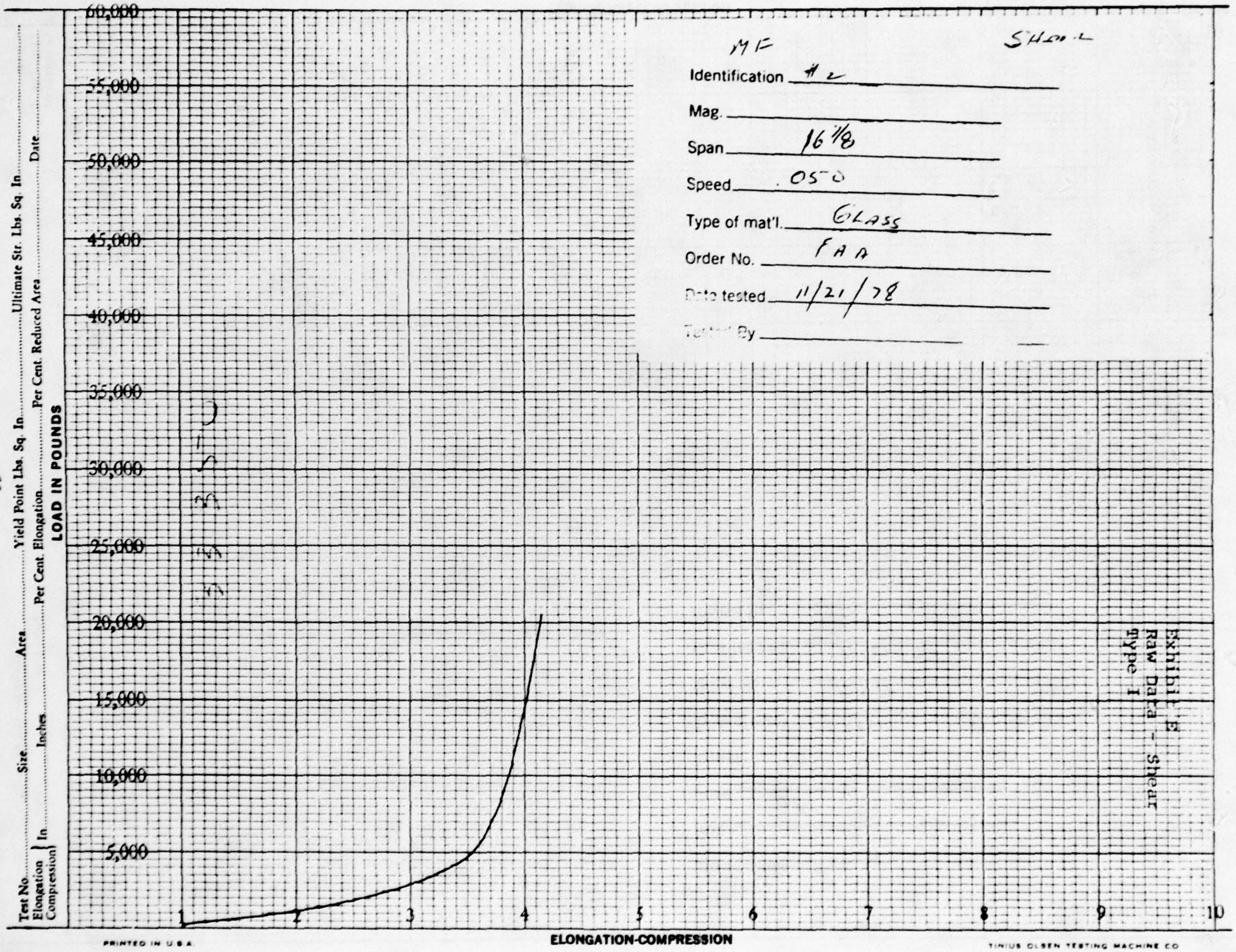
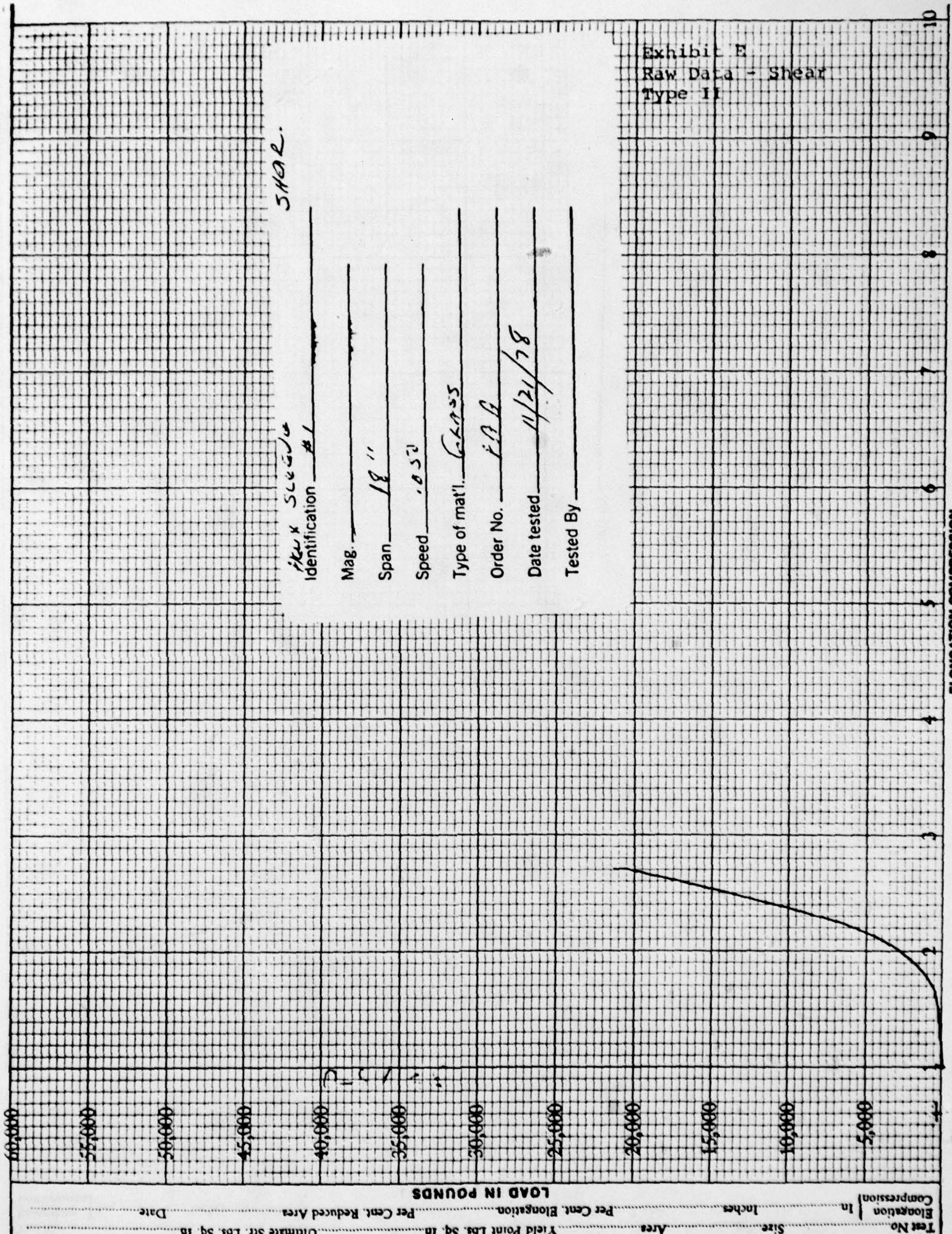

Test No. Size Area Yield Point Lbs. Sq. In. Ultimate Str. Lbs. Sq. In.
Elongation / Compression In. Inches Per Cent. Elongation Per Cent. Reduced Area Date
LOAD IN POUNDS
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
1
2
3
4
5
6
7
8
9
10
ELONGATION-COMPRESSION
MF
SHEAR
Identification #2
Mag.
Span 16 1/8
Speed .050
Type of mat'l. GLASS
Order No. FAA
Date tested 11/21/78
Tested By
Exhibit E
Raw Data - Shear
Type I
PRINTED IN U.S.A.
TINIUS OLSEN TESTING MACHINE CO

Exhibit E
Raw Data - Shear
Type II



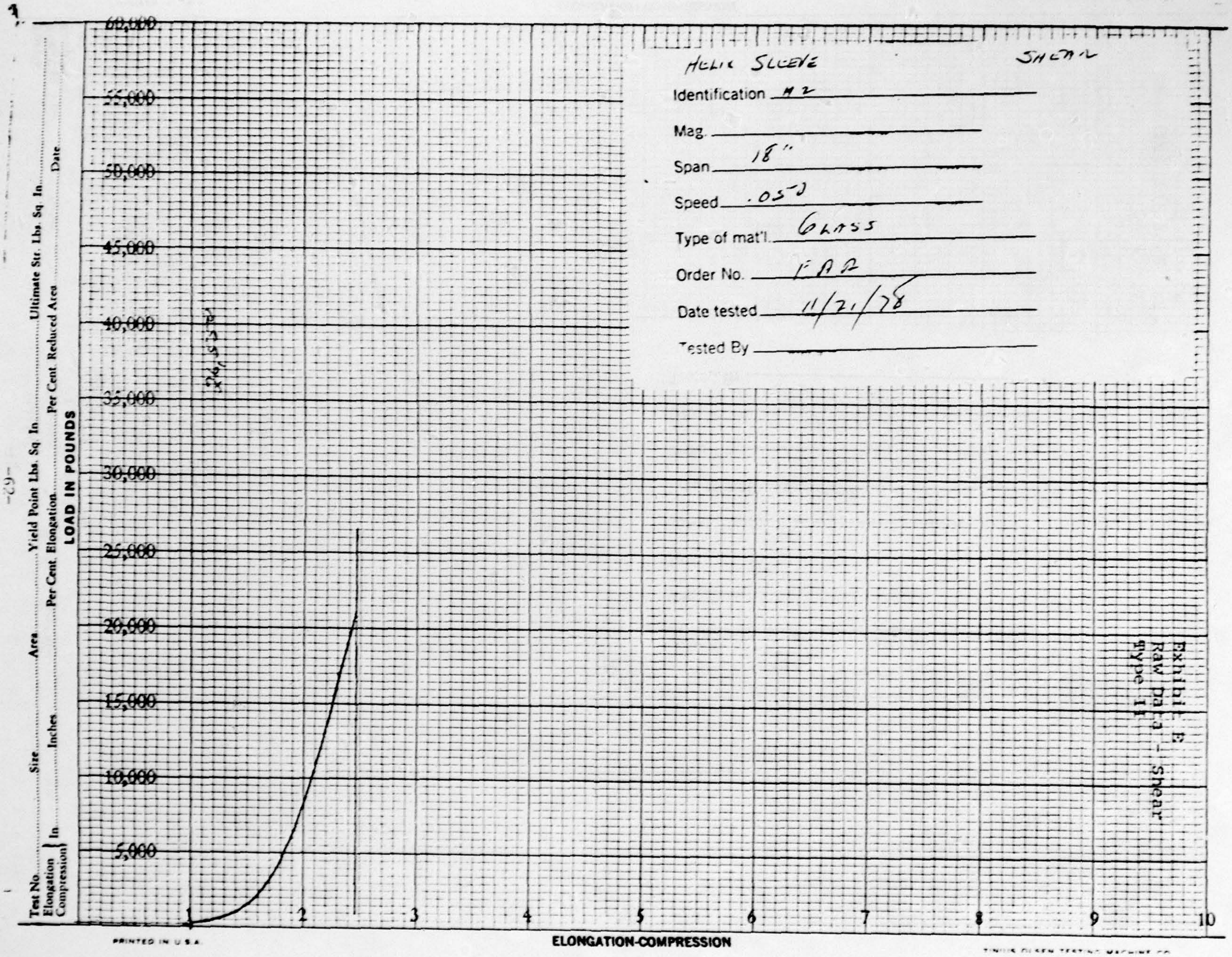

Test No.
Size
Area
Yield Point Lbs. Sq. In.
Ultimate Str. Lbs. Sq. In.
Elongation Compression } In.
Inches
Per Cent. Elongation
Per Cent. Reduced Area
Date
LOAD IN POUNDS
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
1
2
3
4
5
6
7
8
9
10
ELONGATION-COMPRESSION
PRINTED IN U.S.A.
HELIX SLEEVE
SHEAR
Identification H 2
Mag.
Span 18"
Speed .050
Type of mat'l. GLASS
Order No. FAA
Date tested 11/21/78
Tested By
Exhibit E
Raw Data - Shear
Type II

Exhibit E
Raw Data - Shear
Type III

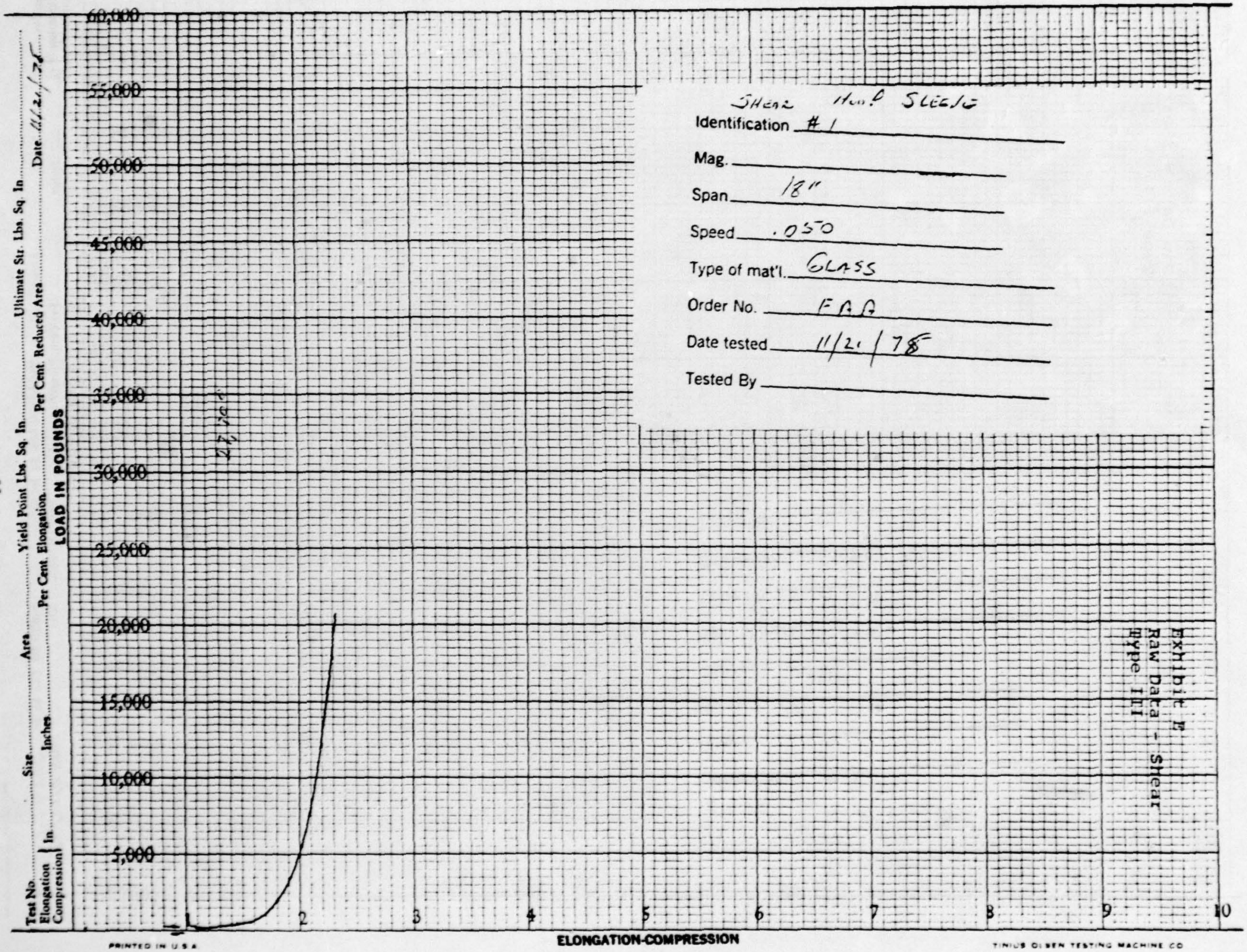


Exhibit E
Raw Data - Shear
Type III

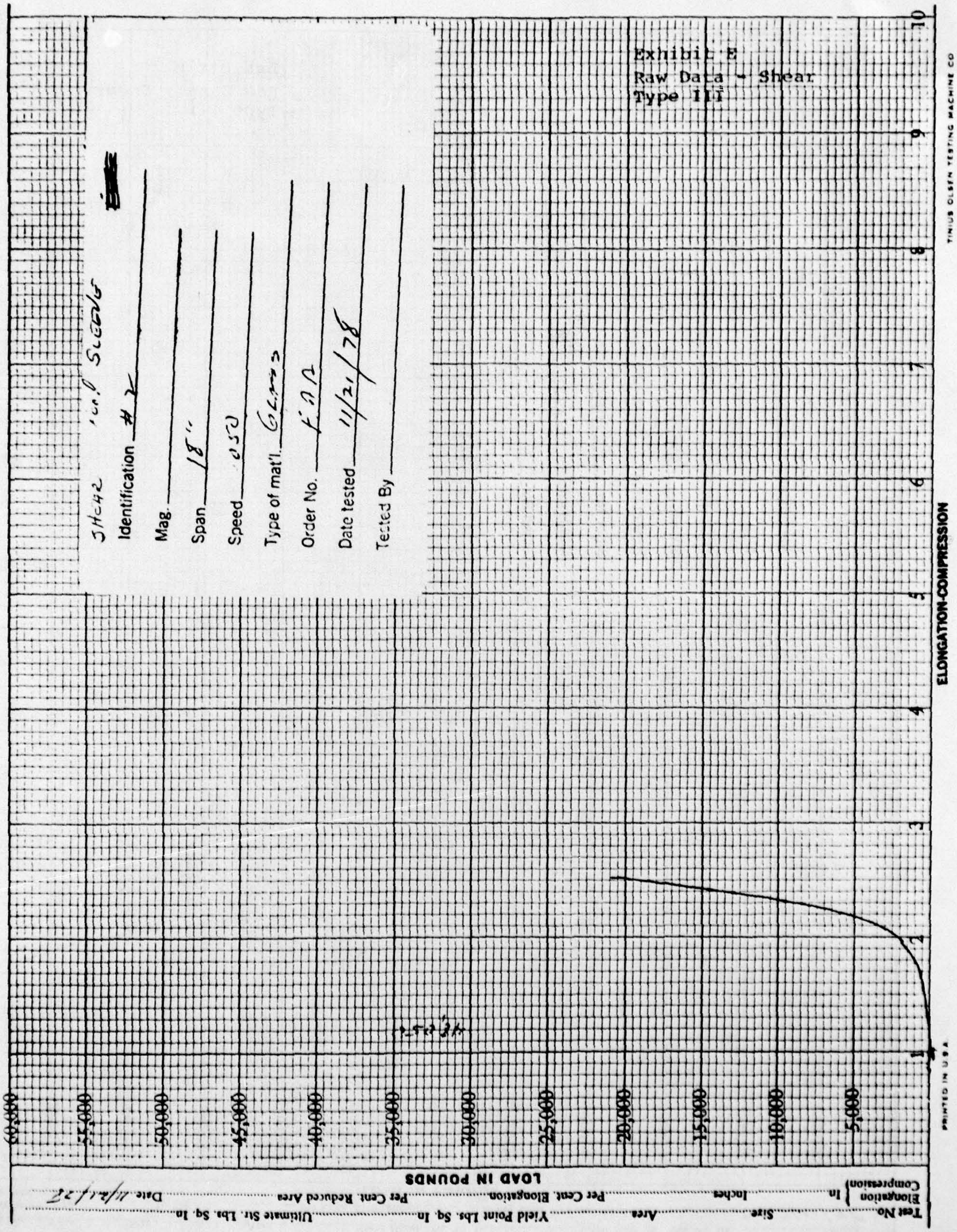


Exhibit E
Raw Data - Shear
Type IV

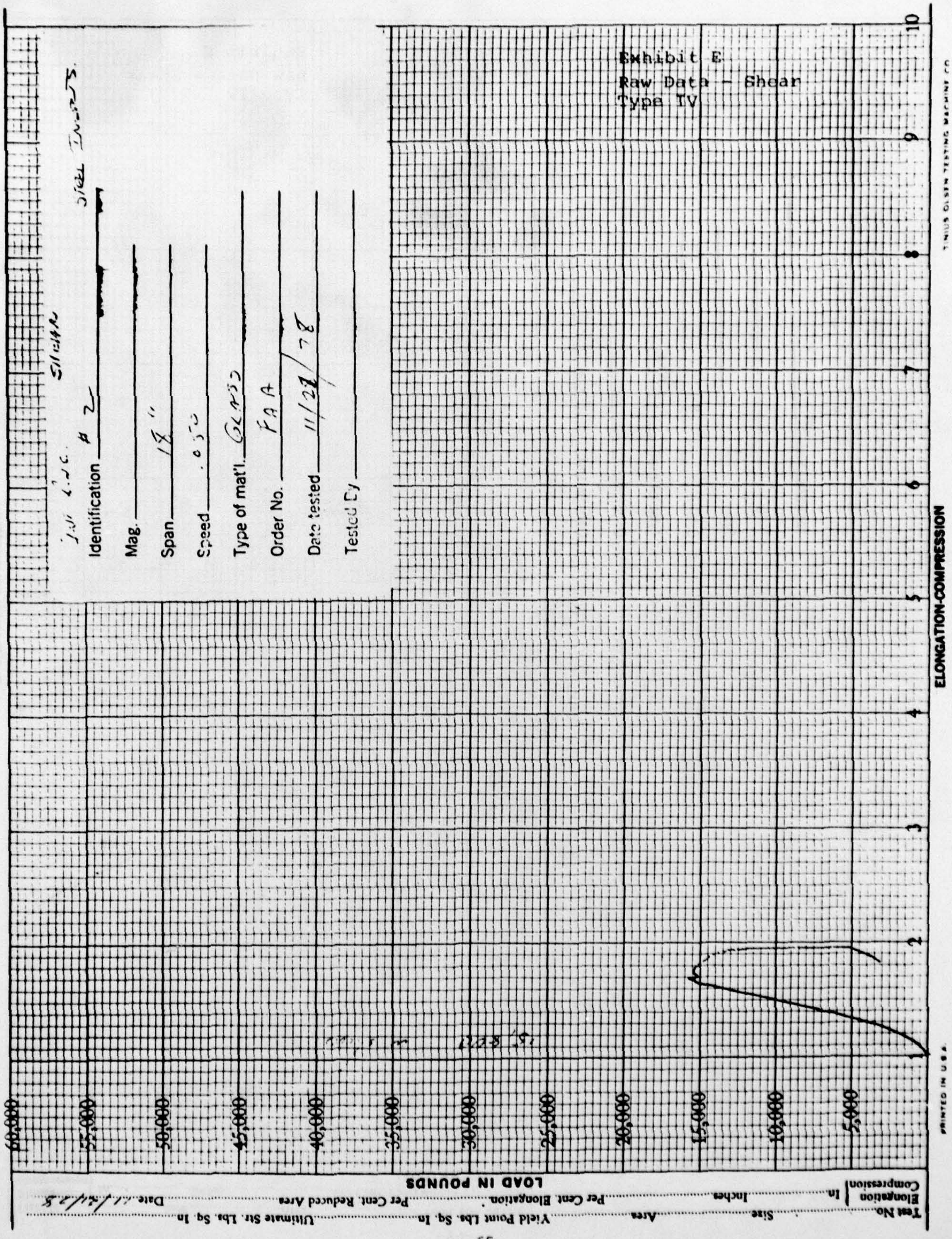


Exhibit E
Raw Data - Shear
Type IV

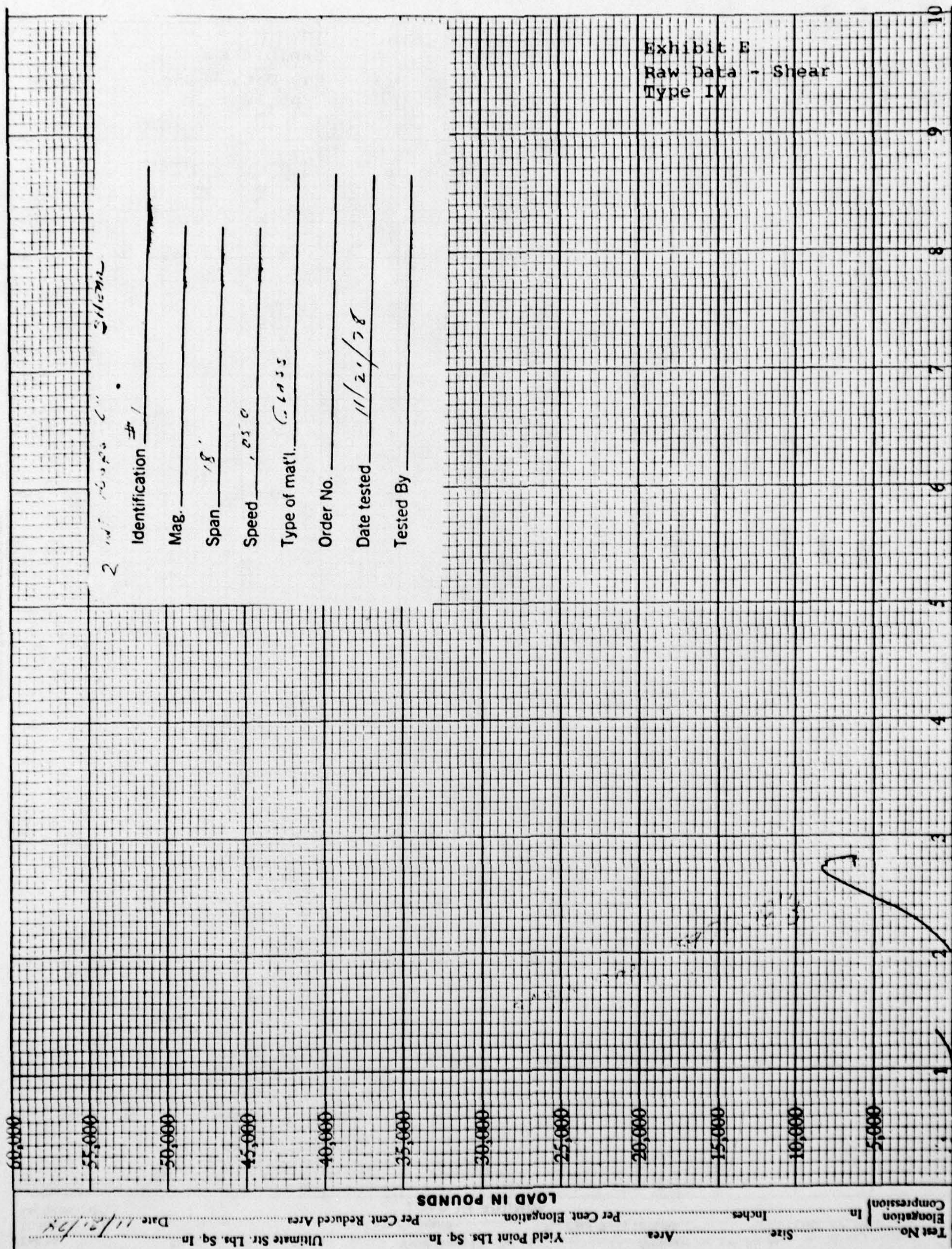


EXHIBIT F

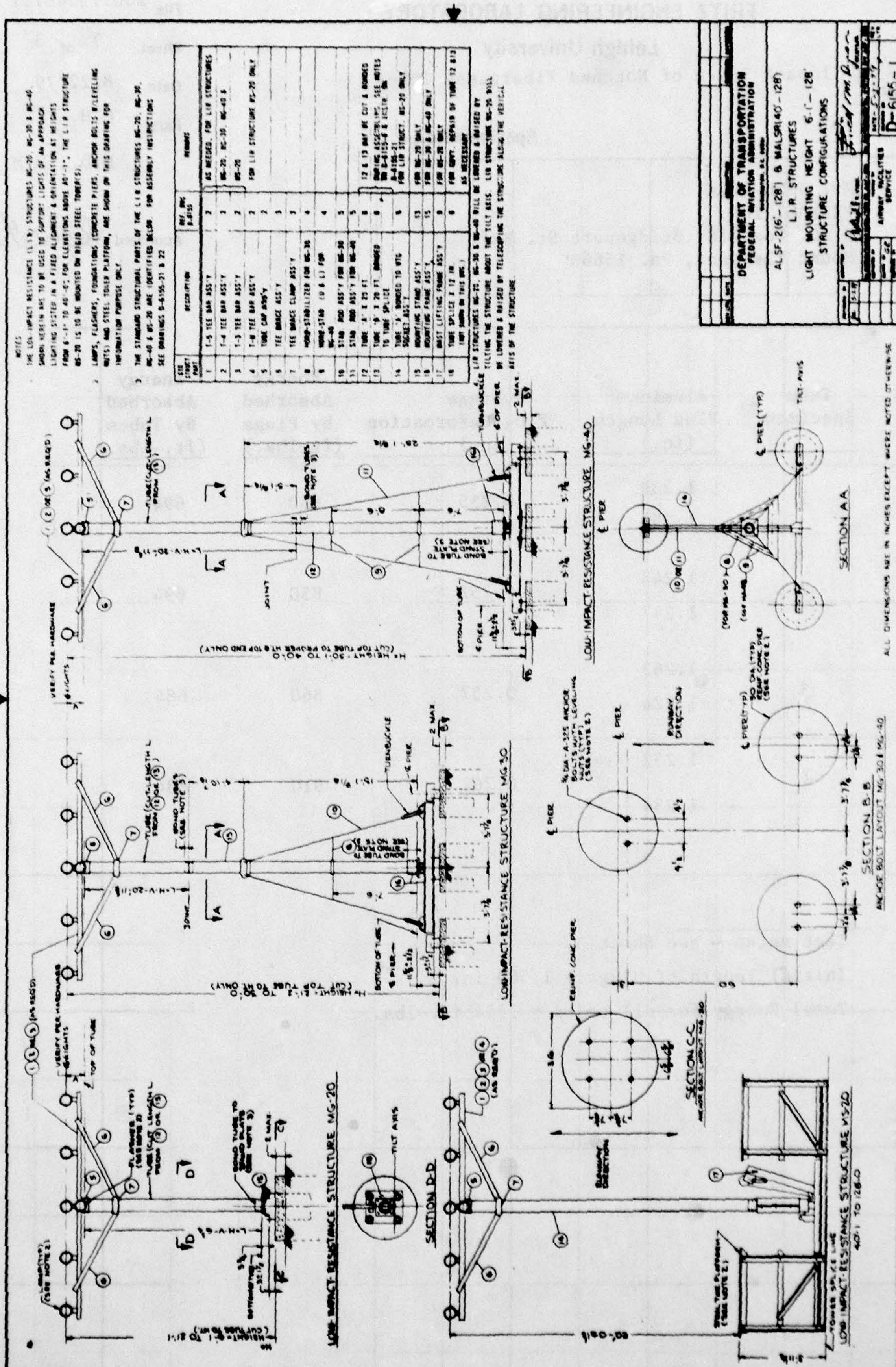

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
ALSF-2(6'-128') & MALSR(40'-128')
L.I.R. STRUCTURES
LIGHT MOUNTING HEIGHT 6'-128'
STRUCTURE CONFIGURATIONS
D-6155-1
LOW-IMPACT-RESISTANCE STRUCTURE MG-20
LOW-IMPACT-RESISTANCE STRUCTURE MG-30
LOW-IMPACT-RESISTANCE STRUCTURE MG-40
SECTION D-D
SECTION C-C
SECTION B-B
SECTION AA
ALL DIMENSIONS ARE IN INCHES EXCEPT WHERE NOTED OTHERWISE

EXHIBIT G

FRITZ ENGINEERING LABORATORY
Lehigh University

File 200.79.487.1
Sheet 1 of 3
Date 8/22/79
Party C.H.
E.D., RJM
Approved Roger G. Slutter

Subject Impact Tests of Notched Fiberglass Tubes

Specimen No.

Mr. John Ross
PERMALI Inc.
P. O. Box 718, Bridgeport St. Ext.
Mount Pleasant, Pa. 15666

Tube Specimen	Aluminum Plug Length (in.)	Average Plug Deformation (in.)	Energy Absorbed by Plugs (ft-lbs.)	Energy Absorbed By Tubes (ft.-lbs.)
1	1.239 1.250	0.255	850	694
2	1.248 1.247	0.252	850	694
3	1.262 1.224	0.257	860	684
4	1.232 1.234	0.267	910	634

Test setup - see Sheet 3

Initial length of plugs = 1.500 in.

Total Energy for all tests = 1544 ft.-lbs.

FRITZ ENGINEERING LABORATORY

Lehigh University

Subject Calibration of Aluminum Plugs with 217.7 lb. Weight

Specimen No.

File 200.79.487.1

Sheet 2 **of** 3

Date 8/22/79

Party CH

ED, RJM

Approved Roger G. Slutter

Mr. John Ross
PERMALI Inc.
P. O.ox 718, Bridgeport St. Ext.
Mount Pleasant, Pa. 15666

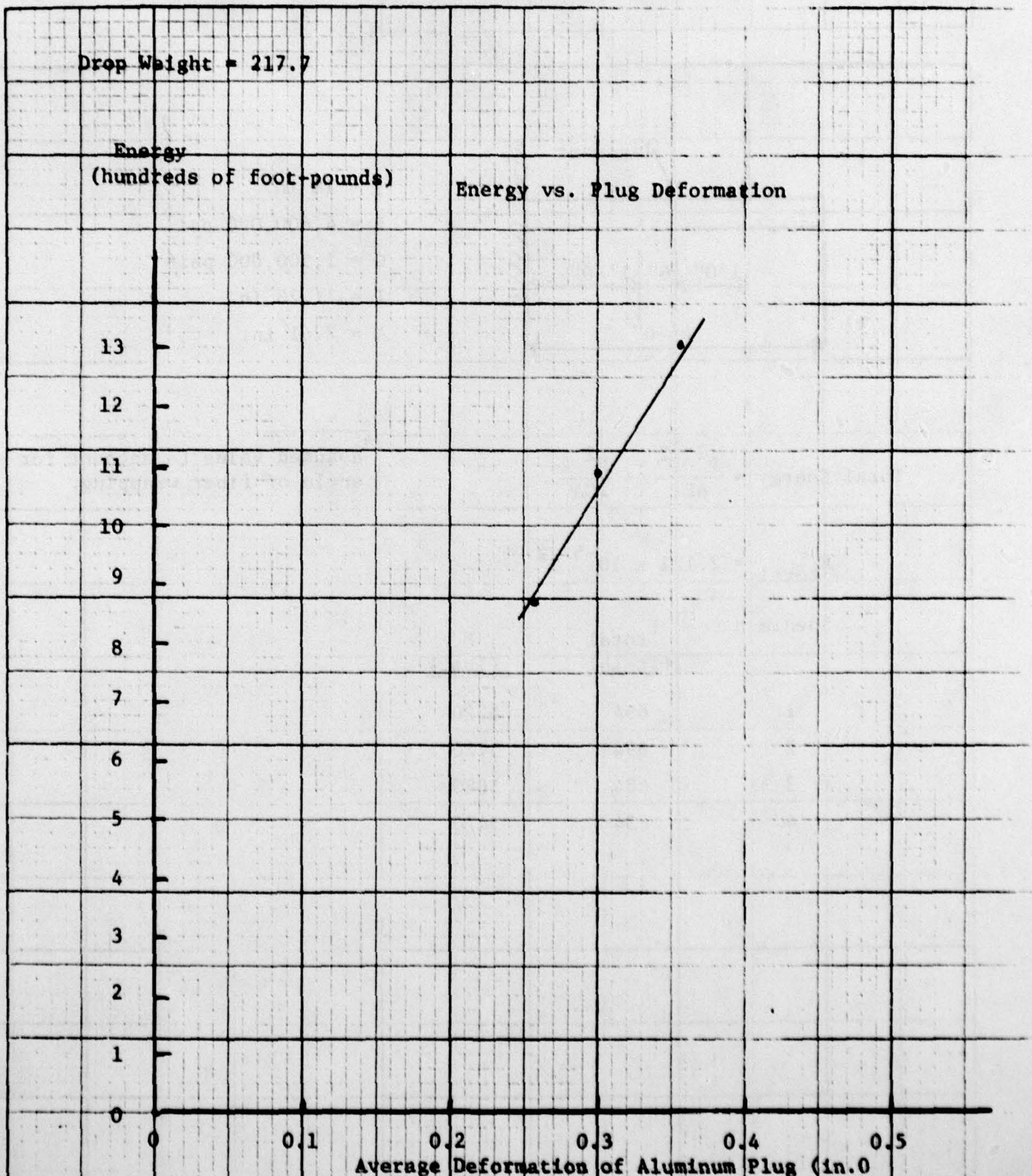


EXHIBIT G

FRITZ ENGINEERING LABORATORY
Lehigh University

File 200.79.487.1

Sheet 3 of 3

Date 8/22/79

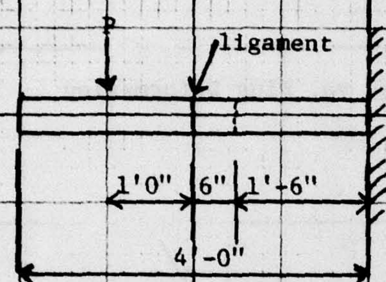
Party CH
ED, RJM

Approved Roger G. Slutter

Subject Calculation of Peak Force for Impact

Specimen No.

John Ross
PERMALI Inc.
P. O. Box 718 Bridgeport St. Ext.
Mount Pleasant, Pa. 15666



ℓ = 18 in.

E = 4,600,000 psi

G = 1,500,000 psi*

I = 11.28 in.

A = 2.41 in.

*assumed value to account for angle of fiber wrapping.

$$\text{Total Energy} = \frac{P^2 \ell^2}{6EI} + \frac{P^2 \ell}{2GA}$$

$$E_{total} = 2.122 \times 10^{-5} P^2$$

Specimen	E_{total} (ft-lb)	P (lbs.)
1	694	5720
2	694	5720
3	684	5680
4	634	5470